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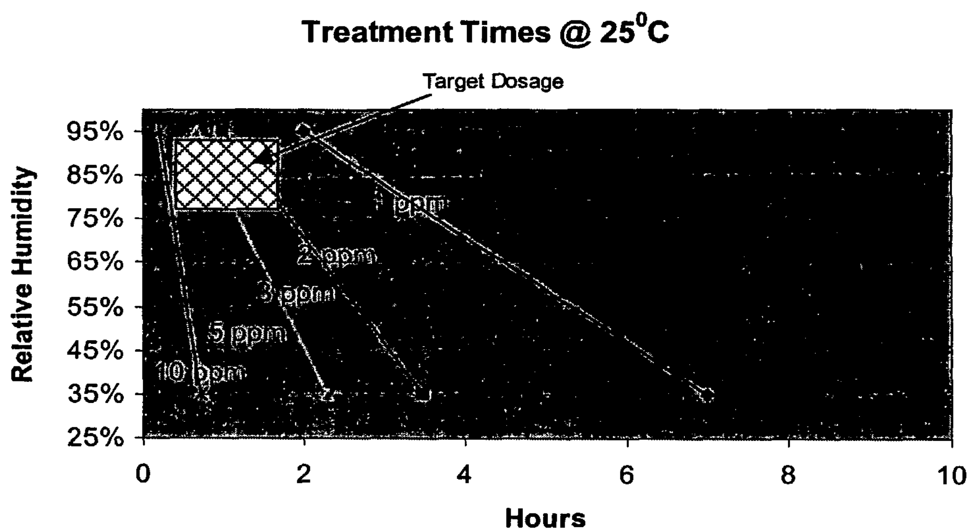
(54) Title: METHOD FOR ABATEMENT OF ALLERGENS, PATHOGENS AND VOLATILE ORGANIC COMPOUNDS




(57) Abstract: The present invention pertains to methods utilizing ozone treatment for abating allergens, pathogens, odors, and volatile organic compounds. The methods can be employed to abate pollutants, bacteria, viruses, mold, dander, funguses, dust mites, animal and smoke odors, and the like. The methods employ specific combinations of ozone concentration, temperature, and humidity to achieve satisfactory abatement of the allergen, pathogen, odor, or volatile organic compound.

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# METHOD FOR ABATEMENT OF ALLERGENS, PATHOGENS AND VOLATILE ORGANIC COMPOUNDS

## Field of the Invention

The present invention pertains to methods utilizing ozone treatment for abating allergens, pathogens, odors, and volatile organic compounds. The methods can be employed to abate pollutants, bacteria, viruses, mold, dander, funguses, dust mites, animal and smoke odors, and the like. The methods employ specific combinations of ozone concentration, temperature, and humidity to achieve satisfactory abatement of the allergen, pathogen, odor, or volatile organic compound.

## Background of the Invention

Building-Related Illness (BRI) is a discrete, identifiable disease or illness that can be traced to a specific pollutant or source within a building. In contrast, the term Sick Building Syndrome (SBS) is used to describe situations in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified. Both syndromes are associated with immediate or potential health problems and are of particular concern as it is estimated that most people spend as much as 90% of their time indoors. It is indoors where EPA studies have shown that the levels of pollutants can be 2-5 times, and occasionally, more than 100 times higher than outdoor levels.

The American Lung Association recently documented a decrease in motivation, performance, and productivity among office workers and school children in relation to poor indoor air quality within buildings. Their evidence involving office workers suggests that when individuals experience only two symptoms of discomfort, they begin to perceive a reduction in their own performance. This perception increases as the number of symptoms increases, averaging 3% loss with three symptoms, and an 8% loss with five symptoms.

The EPA stated in 1991, "The term "Sick Building Syndrome" is used to describe situations in which building occupants experience acute health and discomfort effects that appear to be linked to time spent in a building, but no specific illness or cause can be identified. The complaints can be localized in a particular room or zone, or can be widespread throughout the building. In contrast, the term "Building Related Illness" is used when symptoms can be attributed directly to airborne building contaminants." The EPA has just published a new reference document, "Mold Remediation in Schools and Commercial Buildings" (EPA 402-K-01-001) This publication is the governmental standard for mold and treatment of commercial buildings. The EPA states that mold in commercial buildings contaminates or destroys everything it grows on including building walls, air conditioning, ceiling and carpeting, etc.

Identifying "Sick Buildings" can be difficult. Identifying the actual cause of the 'sickness' can be even more difficult. Molds are a good example of the problems encountered when attempting to identify the source of pollutants. They are present everywhere, both indoors and outdoors. Their effects on people are quite random, some experience extreme symptoms, while others have only minor reactions.

Those who suffer from asthma, hay fever, or other allergies are at a particularly high risk for Building-Related Illnesses. Symptoms can include one or more of the following (ranging from mild to acute): headache; eye, nose or throat irritation; dry or itchy skin; dizziness and nausea; difficulty in concentrating; fatigue; and sensitivity to odors. In the case of Building Related Illnesses, the cause of the symptoms is not obvious, i.e., a cold or flu. The symptoms can linger for several weeks or more. Most of the affected people experience relief after leaving the building. If inhabitants of a building experience these symptoms, then the building's environment can be a factor.

Unhealthy indoor air associated with Sick Building Syndrome and Building Related Illnesses can come from a variety of sources. Most common are dust mites (and their feces), mold, off-gassing chemicals (from carpets, paint, glues and plastics), and natural sources (decaying plants or animals, radon, animals and their dander, people). Many substances can infiltrate our indoor airspaces and then accumulate to a point that leads to illness.

Molds (fungi) can often be associated with Sick Building Syndrome and Building-Related Illnesses. According to an Environmental Protection Agency (EPA) bulletin published in March 2001, "Molds can be found almost anywhere; they can grow on virtually any organic substance, as long as moisture and oxygen are present. There are molds that can grow on wood, paper, carpet, foods, and insulation. When excessive moisture accumulates in buildings or on building materials, mold growth will often occur, particularly if the moisture problem remains undiscovered or unaddressed."

Indoors and outdoors, mold is present everywhere. The term mold applies to the microscopic members of the Fungi kingdom. It is a fuzzy, cobweb-like growth produced on organic matter. Mold has no ability to 'fix' carbon using chlorophyll, so it relies on some type of organic material as a food source. It can spread rapidly, forming the mycelium (fungal body), which is made up of a fine network of filaments (hyphae). The mycelium produces other clusters of root like hyphae, called rhizoids, which penetrate the organic material, secreting enzymes and absorbing water and the digested sugars and starches. Other clusters of hyphae called sporangiophores then reach upward, forming sporangia (knoblike spore cases), which bear the particular color of the mold species. Upon ripening, the sporangia break open and the windborne spores land elsewhere to reproduce asexually. If they find themselves in a less than ideal situation (not sufficient food, water, etc) molds are likely to switch to a nonsexual method of reproduction

(one not involving swapping or combining of genetic material) for the duration. This can make molds hard to identify, since species are classified by their sexual characteristics (e.g., kind of spore cell wall, spore-producing cells, and sacs that store cells). Worldwide there are more than 100,000 species of mold, with at least 1,000 species common in the United States. Some of the most commonly found are species of Cladosporium, Penicillium, and Aspergillus. Mold can be found almost everywhere and it can grow on virtually any organic substance. Mold is most likely to grow where there is water or dampness, such as bathrooms, attics, and basements.

Most types of mold commonly encountered are not hazardous to healthy individuals. However, there are some that have achieved recent notoriety that are strongly toxic such as *Stachybotrys*. *Stachybotrys* is not common but can be very harmful when encountered in quantity. Others, like *Aspergillus*, can be dangerous as well. Aspergillosis is a lung disease suffered generally by immune-compromised people. In this disease, the *Aspergillus* mold actually grows in a person's lungs and can cause death. In general, too much exposure to even common molds can cause or worsen conditions such as asthma, hay fever, or other allergies. Common symptoms of overexposure to mold are cough, congestion, runny nose, eye irritation, and aggravation of asthma. More serious health effects, such as fevers and breathing problems, can occur depending on the amount of exposure and person's individual vulnerability.

When moldy material becomes damaged or disturbed, spore (reproductive bodies similar to seeds) can be released into the air. Exposure can occur if people inhale the spores, directly handle moldy materials, or accidentally ingest it. Mold can sometimes produce chemicals called Mycotoxins, which can also cause illness to sensitive people.

All molds must have water to grow. Mold can grow almost anywhere there is water damage, high humidity, or dampness. Removing the source of moisture is critical to preventing mold growth. Typical water sources utilized by mold in residential environments include air conditioner condensers, roof leaks, pipe leaks, sprinklers adjacent to an outside wall, and the like.

*Stachybotrys Chartarum* (also known as *Stachybotrys atra*) is a type of mold that has been associated with health effects in people. It is a greenish-black mold that can grow on materials with a high cellulose content, such as drywall, hanging ceilings and wood - that has been chronically moist or water damaged, due to excessive humidity, water leaks, condensation or flooding. Numerous molds are black in appearance, but are not Stachybotrys. For example, the black mold commonly found between bathroom tiles is not Stachybotrys. Stachybotrys can only be positively identified via laboratory testing.

Indoor levels of Stachybotrys are typically low; however, as with other types of mold, at higher concentrations health effects can occur. These include allergic rhinitis (cold-like symptoms), dermatitis (rashes), sinusitis, conjunctivitis, and aggravation of asthma. Some related

symptoms are general, such as inability to concentrate and fatigue. Usually, symptoms disappear after the contamination is removed.

There has been some evidence linking Stachybotrys with pulmonary hemosiderosis in infants who are generally less than six months old. Pulmonary hemosiderosis is an uncommon condition that results from bleeding in the lungs. In studies of pulmonary hemosiderosis, the exposure to Stachybotrys came from highly contaminated homes, where infants were continually exposed over a long period of time. Individuals exposed to the mold who exhibit symptoms characteristic of mold exposure should seek appropriate medical attention.

Visible mold can be sampled and analyzed by laboratories specializing in microbiology. However, these tests can be expensive - from hundreds to thousands of dollars. Even if a building is tested for mold, it is difficult to determine at what levels health effects can possibly occur. Therefore, it is important to attack any mold infestation. For small infestations, bleach and water can be effective to kill the mold growth. For larger infestations, more extensive treatment wherein large areas of a building or the whole building are treated can be necessary to kill all of the mold. Once the mold is destroyed, the next step is to find the mold's source of water. Mold will not grow without water, so to prevent its return, its source of water must be located and eliminated. In order to adequately remediate a mold infestation, it is necessary to both destroy the mold and to eliminate the mold's source of water.

While mold infestation itself is not becoming more common, knowledge of it and the problems it can cause is becoming more widely disseminated. In the last few years there have been many widely publicized cases concerning sicknesses caused by mold and the multi-million dollar settlements awarded to those who suffered the consequences of mold toxicity. As well, there have been reports of individuals who have burned their houses down because that was a cheaper solution than remediation of the mold-caused damage. Removal of moldy materials can involve procedures similar to those associated with removal of toxic waste material, such as asbestos, which means that any remediation can be extremely expensive to conduct. It is because of all this publicity that there is an appearance that mold has become more prevalent when in fact it has only become more recognized for its undesirable qualities.

Other pathogens, allergens, and odors, e.g., dust mite feces, fungi, spores, pollen, mildew, bacteria, viruses, amoebas, fragments of plant materials, human and animal dander, proteins that that cause allergic reaction such as the ones in dust mite feces and animal dander, feather dust, litter dust, tobacco smoke, smoke from fires, volatile organic compounds, and other bioaerosols and inorganic aerosols and gases, can also be the cause of Building Related Illnesses. For example, the feces of household dust mites can cause allergic reactions. A gram of house dust (approximately half of a teaspoon) can contain as many as 1,000 dust mites. That same amount of dust could hold over 250,000 of their fecal pellets. Once airborne, dried dust mite droppings are so

small that they are easily inhaled causing allergic reactions in many people. These reactions can range from sneezing, coughing, itchy eyes and sniffles to asthma, eczema, even snoring. House dust mites are related to spiders. They are eight legged creatures invisible to the human eye. They survive by eating dead skin cells. A dust mite will produce 20 fecal pellets per day, which is 200 times its own body weight, during its short lifetime. The greatest number of dust mites in the home is usually found in the bedroom, specifically in the bedding and pillow. The skin and moisture shed each night provide ideal conditions for their growth. Millions of mites can be present in bedding, and up to 10% of a two-year-old pillow's weight can be made up of house dust mites and their droppings.

Pets are another source of allergens. Household pets are the most common source of allergic reactions to children. It is estimated that 10 million animal owners may be allergic to their animals, and 20% to 30% of the people who have asthma are also allergic to animals. Many people react to animal allergies in extremely different manners. For some people, animal odors, dander, saliva and urine can cause allergic reactions. Animal fur can also collect outdoor pollens, mold spores, and other outdoor allergens that are then brought indoors. A recent study reviewed by the American Academy of Allergy, Asthma and Immunology, indicated that approximately 80% of the animal owners surveyed keep their animals indoors most of the time. These findings may help explain why allergy symptoms, such as itchy and watery eyes, sneezing, coughing, wheezing and hives in allergic children and adults, worsen with continued exposure to animals.

The American Lung Association's "Health House Project" stated that "[a]ccording to a recent study published in Pediatrics magazine, asthma cases could drop nearly 40% among America children under age 6 if susceptible youngsters did not have pets or other allergy triggers in their home. The study also found that children with animal allergies were 24 times more likely to have asthma than those without such allergies."

One of the more difficult problems with allergies to animals is it can take two years or more to develop in a home and may not subside until 6 months or more after the animal has been removed from the home. Carpeting and furniture can act as reservoirs for animal dander and allergens. The animal dander can become a food source for common household dust mites. These pest and allergens can also find their way throughout the homes' heating and air condition system.

The elderly, young children and infants in particular, are especially susceptible to negative reactions to allergens and pathogens. Many magazines, such as Harper's Bazaar and Parent's have articles on how to clean and prepare a home for a new infant. Harper's has a Wellness Report that contains a home purity checklist that cites mold, dust mites, and animal dander as major home health concerns. As mentioned above, of major concern to infants is animal dander that can trigger sniffling, stuffy noses, and sneezing and water eyes. Dust mites are a known trigger for asthma, and found everywhere.

Of serious concern to infants is mold, which comes from persistent leaks from air conditioners and plumbing that can lead to airborne mold, which aggravates allergies. Some indoor molds have the potential to produce extremely potent toxins called Mycotoxins. Mycotoxins are readily absorbed by the intestinal lining, airways, and skin. Molds that produce potent toxins have been associated with acute pulmonary hemorrhage among 37 infants from the Cleveland, Ohio, area between 1993 and 1998. Twelve of these children died. As stated by Dr. Henry Fishman M.D. P.C., Diplomat American Board of Allergy and Immunology, American Board of Internal Medicine and National Board of Medical Examiners, "There is a body of evidence that indoor allergies, particularly dust mites, may cause asthma in some infants. Without the dust mite sensitivity, asthma does not develop. Untreated asthma in pregnant women can lead to early deliveries, miscarriages and low birth weight infants. Indoor allergens can make this worse. Also allergies can lead to infections. Kids' immune systems cannot handle the infections burden as well as an adult. So kids with allergies have trouble with infections which can bother their tiny lungs. In other words, in some sensitive kids, allergies have a huge impact on their nose, sinuses and lungs."

Commercial buildings often present special concerns regarding Sick Building Syndrome, Building Related Illnesses. According to Business Week Magazine, today's business office is home to as many as 30 different volatile organic chemicals released by building materials, furnishing and office equipment. Some of the biggest offenders are sealed windows, carpets and padding, carcinogenic cleaning products, the office restroom, cafeterias and kitchen areas, and building renovations. Many people work in enclosed building or offices. Not being able to open windows means you do not always have enough fresh air to circulate within the building. Many carpets, rugs, and paddings are made in part from petrochemicals. An example is formaldehyde odor which is often noticed for a few weeks after new carpet is installed. The same is true with products used in the interiors of new cars. The odor being released is called "out gassing." It often affects people with allergies or sensitive skin. There are over 70,000 identified chemical cleaning products on the market that are used to clean buildings and offices. Some of them contain toxic solvents that, it is claimed, are considered safe when used properly. Clogged toilets and flooded restrooms can create toxic mold and airborne mold spores in area that are difficult to continually inspect. Many buildings have common lunch and food areas that must be maintained within local Health Department standards. Office construction and remodeling can cause mold to spread throughout a building in the matter of a few minutes according to EPA testing. Mold and contaminated dust can cause employees serious health problems.

Problems associated with Sick Building Syndrome have been extensively reported in the media. Media coverage has shown buildings being condemned; structures being burned down to destroy toxic and mold contaminates. Business and consumer magazines such as *Business Week*,

*Time, The Wall Street Journal, Reader's Digest* and *People Magazine* are reporting insurance claims cases and medical awards to people that have been harmed by these toxic conditions. In every case, the courts decisions held that the condition could and should have been treat earlier by the building owners or insurance companies. Television networks are giving coverage to this problem as a major health and business issue.

Erin Brockovich, antipollution crusader, was featured on CBS News broadcast *"48 Hours,"* because her home is infested with the toxic *stachybotrys* mold. NBC Nightly News coverage of the Melinda Ballard's toxic infestation case stated "A Texas jury decided her insurer committed fraud and mishandled her claim, awarding her $32 million."

In the August, 2000 issue of *Claims Magazine*, an insurance industry publication, "a jury recently awarded more than $40 million in personal injury claims. There were over 200 workers' compensation claims and at least 180 separate lawsuits. Previously, such lofty figures were seen only in asbestos or drug-related class actions. Now, we are starting to hear 11-digit figures mentioned in litigation concerning the lowly mold fungi."

*The Lawyers Weekly USA*, a national publication, stated in their October 6, 2000 edition, that claims for personal injury and property damage caused by mold growing inside buildings are on the rise, and one of the "hottest areas" in construction defect and toxic tort law.

The United Press International reports in a feature story titled "Toxic mold a growing legal issue" that, "Mold contamination claims were virtually unheard of a few years ago, but people are becoming more aware of indoor air quality issues because of the expanding scientific and medical knowledge of the toxic effects of mold.

## Summary of the Invention

A method for abating or remediating pathogens or allergens in a commercial or residential setting that ensures the elimination of the maximum number of chemical pollutants, bacteria, viruses, mold, allergens and other fungi, as well as urine and smoke odors possible within the treated area is therefore desirable. It is also desirable that the method leaves no residual chemicals behind, only a fresh, clean smell. A method that may be conducted by trained technicians in a safe and time effective manner, and may preferably be completed at a time when the premises is likely to be vacated (working/school hours for a home, evening hours for an office/commercial location), allowing minimal disruption to a company's or family's daily routine is desirable as well. Particularly desirable is a method that is capable of treating both small as well as large interior areas, and multi-floor or separate locations, as well as major infestations of various types of molds, including toxic molds, without the need for hazardous material precautions, is also desirable.

It is noted that tabletop and room unit ozone generators are marketed to the consumer as means of improving indoor air quality. *Consumer Reports* (1992), the National Institute of Occupational Safety and Health (NIOSH) (Boeniger, 1995), and the U.S. EPA (1995) concluded

that tabletop and room unit ozone generators are not effective in improving indoor air quality. A recent study by the U.S. EPA concluded that ozone is not effective for killing airborne molds and fungi even at high concentrations (6-9 ppm) (U.S. EPA, 1995). In contrast to this earlier work, it has been determined that that selected conditions of ozone concentration, humidity, and temperature are highly effective at killing airborne molds and fungi at even lower ozone concentrations.

Although mold abatement is primarily referred to in regard to the preferred embodiments, it is to be understood that the methods described are suitable for use in abating other substances, including, but not limited to, pathogens, allergens, and odors, including, but not limited to, dust mites, other fungi, spores, pollen, mildew, bacteria, viruses, amoebas, fragments of plant materials, human and animal dander, feather dust, litter dust, tobacco smoke, volatile organic compounds, and other bioaerosols and inorganic aerosols and gases.

In preferred embodiments, ozone (commonly referred to as activated oxygen) is used in the abatement process. Ozone is one of the most powerful sanitizers and deodorizers known. Ozone is a natural component of ambient air. The highest levels of naturally occurring ozone are found in forests, mountains and along seashores. Ozone is created when the energy from ultra violet light or a lightning discharge changes the oxygen molecules ($O_2$) into ozone ($O_3$). This ozone molecule is highly unstable and readily reverts back to $O_2$. When it does revert back to $O_2$ the extra oxygen atom that it releases reacts with another compound (for example a malodorous compound, or the surface of a germ, or mold) changing that compound or microorganism in the process. Given sufficient ozone over a short period of time, enough oxygen atoms are produced to convert the compound into a new and usually less contaminating one.

Bacteria, fungi (molds and mildew) which can cause unpleasant odors, allergic reactions and sometimes disease, are destroyed when they come into contact with ozone. As with chemical pollutants, the outer membranes or shells of these microorganisms contain receptors that ozone attacks and, if sufficient ozone is present, break down. Without its protective membrane or shell, the microorganism dies quickly.

The methods of preferred embodiments utilize the chemical characteristics of ozone to generate a highly effective natural sanitizer while ensuring the proper protection for building occupants and technicians administering the treatment. The end result is a highly purified space with cleaned air containing oxygen as the only residual substance generated by the process.

In a first embodiment, a method for abating a pathogen, allergen, or odor is provided, the method including the step of exposing the pathogen, allergen, or odor to an atmosphere including an ozone concentration of from about 2 ppm to about 5 ppm, a relative humidity of from about 70% to about 90%, and a temperature of from about 15°C to about 27°C for at least a time of from about 1 hour to about 3 hours, whereby the pathogen, allergen, or odor is abated.

In an aspect of the first embodiment, a pathogen is abated, the pathogen including a species of mold.

In an aspect of the first embodiment, a pathogen is abated, the pathogen including Norwalk virus.

In an aspect of the first embodiment, a pathogen is abated, the pathogen including anthrax.

In an aspect of the first embodiment, an allergen is abated, the allergen including dust mite feces.

In an aspect of the first embodiment, an allergen is abated, the allergen including dander.

In an aspect of the first embodiment, an allergen is abated, the allergen including a protein capable of inducing an allergic reaction in a human susceptible thereto.

In an aspect of the first embodiment, an allergen is abated, the allergen including tobacco smoke.

In an aspect of the first embodiment, an odor is abated, the odor including a volatile organic compound.

In an aspect of the first embodiment, an odor is abated, the odor including urine.

In a second embodiment, a method for abating a pathogen, allergen, or odor in an enclosed space in which air can circulate freely is provided, the method including the steps of: sealing the space such that conditions of ozone concentration, temperature, and relative humidity can be controlled within the space; providing ozone to the air of the space until a concentration of at least about 2 ppm to about 5 ppm is achieved in all areas of the space; maintaining the concentration of ozone in the air of the space at a level of about 2 ppm to about 5 ppm for at least a time of from about 1 hour to about 3 hours; providing moisture to the air in the space until a level of relative humidity within the space reaches about 70% to about 90%; and controlling the temperature within the space at about 15°C to about 27°C, wherein the steps of controlling the relative humidity and controlling the temperature are conducted substantially simultaneously as the step of maintaining the concentration of ozone, whereby the pathogen, allergen, or odor is abated.

In an aspect of the second embodiment, the method further includes the steps of ceasing providing ozone to the air of the space; and permitting the concentration of ozone in the air of the space to return to an ambient level.

In an aspect of the second embodiment, the method further includes the step of: exposing a material in the space to ultraviolet light, whereby an odor associated with ozone or an allergic reaction to ozone is reduced, wherein the step is performed after ceasing providing ozone.

In an aspect of the second embodiment, the method further includes the step of: exposing the space to a temperature above 27°C, whereby an odor associated with ozone or an allergic reaction to ozone is reduced, wherein the step is performed after ceasing providing ozone.

In an aspect of the second embodiment, the method further includes the step of providing ions to the space, whereby an odor associated with ozone or an allergic reaction to ozone is reduced. The step of providing ions can be conducted before, during, or after the step of maintaining the concentration of ozone. The ions can include positive ions, negative ions, or positive ions and negative ions. The ions can be generated by a bipolar ion generator employing a pulsed AC system to generate positive ions and negative ions in surrounding air.

In an aspect of the second embodiment, the method further includes the step of exposing the space to a humidity of 70% to about 90%, wherein the step is conducted before the step of providing ozone.

In an aspect of the second embodiment, the space includes a building.

In an aspect of the second embodiment, the space includes a room of a building.

In an aspect of the second embodiment, the building includes a dwelling.

In an aspect of the second embodiment, the space includes a ship, a passenger car, a mobile home or a motor home.

In a third embodiment, a method for abating a pathogen, allergen, or odor in an enclosed space containing obstacles that greatly inhibit but do not entirely prevent the circulation of air is provided, the method including the steps of: providing an ingress into a first end of the space; providing an egress out of a second end of the space, wherein the first end of the space and the second end of the space are situated on opposite sides of the space; providing ozone to the space via the ingress; maintaining the concentration of ozone in the air of the space as measured at the egress at a level of about 2 ppm to about 5 ppm for at least a time of from about 1 hour to about 3 hours; controlling the relative humidity within the space at about 70% to about 90%; and controlling the temperature within the space at about 15°C to about 27°C, wherein the steps of controlling the relative humidity and controlling the temperature are conducted substantially simultaneously as the step of maintaining the concentration of ozone, whereby the pathogen, allergen, or odor is abated.

In an aspect of the third embodiment, the method further includes the steps of ceasing providing ozone to the air of the space; and permitting the concentration of ozone in the air of the space to return to an ambient level.

In an aspect of the third embodiment, the space includes an interior of a wall in a building.

In an aspect of the third embodiment, the space includes the interior of floor of a building.

In an aspect of the third embodiment, the space includes an interior of a ceiling in a building.

## Brief Description of the Drawings

Figure 1 provides a schematic of an ozone generator and humidifier system capable of delivering ozone at a rate of 60 g/hour.

Figure 2 provides a graph depicting optimal conditions of ozone concentration, treatment times, and humidity at a temperature of 5°C (41°F).

Figure 3 provides a graph depicting optimal conditions of ozone concentration, treatment times, and humidity at a temperature of 15°C (59°F).

Figure 4 provides a graph depicting optimal conditions of ozone concentration, treatment times, and humidity at a temperature of 25°C (77°F).

Figure 5 provides levels (spores/$m^3$) of cladosporium spores, ascospores, basidiospores, periconia/myxomycetes, penicillium/aspergillus, algae, ganodera basidiospores, and alternaria spores in the air in a dining room of a Santa Monica, California home before and after treatment, and outdoors.

Figure 6 provides levels (spores/$m^3$) of cladosporium spores, ascospores, basidiospores, periconia/myxomycetes, penicillium/aspergillus, algae, ganodera basidiospores, and alternaria spores in the air in a master bedroom of a Santa Monica, California home before and after treatment, and outdoors.

Figure 7 provides levels (spores/$m^3$) of cladosporium spores, ascospores, basidiospores, periconia/myxomycetes, penicillium/aspergillus, algae, ganodera basidiospores, and alternaria spores in the air in a second bedroom of a Santa Monica, California home before and after treatment, and outdoors.

## Detailed Description of the Preferred Embodiment

The following description and examples illustrate a preferred embodiment of the present invention in detail. Those of skill in the art will recognize that there are numerous variations and modifications of this invention that are encompassed by its scope. Accordingly, the description of a preferred embodiment should not be deemed to limit the scope of the present invention.

The processes of preferred embodiments use high concentrations of ozone. The process involves optimizing treatment conditions by employing a relationship between ozone concentration, humidity, temperature, duration of treatment, volume of space, and condition being treated. This relationship, termed the 'target dosage' calculation, has been determined by laboratory experimentation and field testing. By utilizing these target dosages to apply a prescribed concentration of ozone for a prescribed period of time in a strictly controlled area, the elimination of most odors, bacteria, viruses, and molds can be achieved. When the treatment is completed, the ozone generators are removed from the treated area and fans are employed to replace the ozonated air with fresh outside air through just-opened doors and windows. The ozone is thereby evacuated and concentrations in the treated area are returned to a level that is no higher than the outdoor ambient level, resulting in an improvement in indoor air quality.

Ozone has a long history of use in purification methods. The Food and Drug Administration approved ozone for use in food preservation in June 2001. Currently ozone is used

to purify drinking water as well as such other diverse tasks as keeping fruits and vegetables fresh during storage. Low powered ozone generators have been available for many years for in-home use, however these units have proven to be very problematic. The units that are safe to operate with people present generate levels of ozone that are too low to be effective in abating mold and other pathogens and allergens. The more powerful units that are effective in decontaminating a room or house generate levels of ozone that are unsafe for continuous occupation.

The concentrations of ozone used in the methods of preferred embodiments can cause lung irritation, so exposure during treatment is avoided. During the process, all animals and people remain outside the area being treated. However, in less than an hour following a treatment, the ozone levels in the area treated can be reduced to that of the outside air and no harmful residual substances are left behind.

The process of the preferred embodiments kills the mold it comes into contact with. However, mold that is inside of walls or in other areas not accessible to freely circulating air can necessitate special steps in order to ensure all of the mold is killed.

There is no way to determine how long a treated premises will remain contaminant free. Mold can be effectively abated by the methods of preferred embodiments. However, if the mold's supply of water is not removed the mold can return. Similar principles apply to other contaminants. As long as they are kept from reentering, the premises remains contaminant free.

While living things, such as people, animals and sensitive plants are removed from the premises while the house is being treated, the process does not harm anything else, e.g., exposed surfaces such as textiles, carpets, paper, paint, and the like, or household goods such as furnishings or electronics. The treatment does not leave behind a film or residue of any kind, only a clean, fresh interior environment.

Fish, curry, garlic, onion and other stubborn cooking odors, along with smoking and animal odors are easily removed from the air, as well as from furniture, bedding and carpets, by the methods of preferred embodiments. Note that animal smells originating from places where the animal has heavily urinated are not easily cleaned due to the concentration of urine present. It is preferred to pre-treat such stubborn areas with an enzymatic cleaner prior to treatment according to the preferred embodiments.

The methods of preferred embodiments have the major advantage of not requiring tenting of the house, or extreme measures to seal off egresses. The methods are also quick. Typically, five hours is sufficient to treat a typical indoor space of 25,000 cu. ft. or less. An average treatment typically takes four hours to complete with another hour for equipment removal, venting of ozone-containing air, and post treatment evaluation of the premises. However treatments can last from seconds to minutes, hours, or even days, depending on the target dosage.

The method is effective in removing odors associated with volatile organic compounds. However, as noted above, if the source of the odor is not eliminated, the odor can return.

While the method of preferred embodiments is especially preferred for abating mold in residential and commercial buildings, it is also effective in treating other structures, such as boats. Surface mold and fuel odors can be eliminated, along with unpleasant aromas from the bilge and head. The process is particularly successful in taking out the musty smells in motor homes that have been closed up for the season or ones that are experiencing fuel smells or cooking odors. Any area or structure that is affected by pathogens, allergens, or undesirable odors can be amenable to treatment according to methods of the preferred embodiments, including cars, trucks, passenger buses, aircraft, train cars, and the like.

It is often preferred to treat a premises according to the methods of preferred embodiments on a regular basis, e.g., monthly, quarterly, semi-annually, or the like, so as to maintain a satisfactory air quality level in the premises and avoid recurrence of mold infestations and the buildup of other allergens such as dust mites and pet dander.

Abated Substances

Methods of preferred embodiments can be employed to abate any of the substances discussed herein, but the methods are particularly preferred for pathogens, molds, allergens, and Volatile Organic Compounds (VOCs).

Pathogens that can be controlled by methods of preferred embodiments include, but are not limited to Anthrax (Bacillus anthracis); Botulism (Clostridium botulinum toxin); Brucella species (brucellosis); Brucellosis (Brucella species); Burkholderia mallei (glanders); Burkholderia pseudomallei (melioidosis); Chlamydia psittaci (psittacosis); Cholera (Vibrio cholerae); Clostridium botulinum toxin (botulism); Clostridium perfringens (Epsilon toxin); Coxiella burnetii (Q fever); E. coli O157:H7 (Escherichia coli); Emerging infectious diseases such as Nipah virus and hantavirus; Norwalk virus; Severe Acute Respiratory Syndrome (SARS); Acquired Immune Deficiency Syndrome (AIDS) virus; Human Immunodeficiency Virus (HIV); Epsilon toxin of Clostridium perfringens; Escherichia coli O157:H7 (E. coli); Food safety threats (e.g., Salmonella species, Escherichia coli O157:H7, Shigella); Francisella tularensis (tularemia); Glanders (Burkholderia mallei); Melioidosis (Burkholderia pseudomallei); Plague (Yersinia pestis); Psittacosis (Chlamydia psittaci); Q fever (Coxiella burnetii); Ricin toxin from Ricinus communis (castor beans); Rickettsia prowazekii (typhus fever); Salmonella species (salmonellosis); Salmonella Typhi (typhoid fever); Salmonellosis (Salmonella species); Shigella (shigellosis); Shigellosis (Shigella); Smallpox (variola major); Staphylococcal enterotoxin B; Tularemia (Francisella tularensis); Typhoid fever (Salmonella Typhi); Typhus fever (Rickettsia prowazekii); Variola major (smallpox); Vibrio cholerae (cholera); Viral encephalitis (alphaviruses [e.g., Venezuelan equine encephalitis, eastern equine encephalitis, western equine encephalitis]); Viral

hemorrhagic fevers (filoviruses [e.g., Ebola, Marburg] and arenaviruses [e.g., Lassa, Machupo]); Water safety threats (e.g., Vibrio cholerae, Cryptosporidium parvum); and Yersinia pestis (plague).

Common household molds that can be remediated by methods of preferred embodiments include, but are not limited to *Acremonium; Alternaria; Aspergillus fumigatus; Aspergillus niger; Aspergillus species* Var. 1*; Aspergillus species* Var. 2*; Aureobasidium; Bipolaris; Chaetomium; Cladosporium; Curvularia; Epicoccum; Fusarium; Geotrichum; Memnoniella; Mucor; Mycelia sterilia; Nigrospora; Paecilomyces; Penicillium species* Var. 1*; Penicillium species* Var. 2*; Pithomyces; Rhizopus; Sporothrix; Sporotrichum; Stachybotrys; Syncephalastrum; Trichoderma;* and Yeast. Molds need high humidity levels and a surface on which to grow. Common areas for mold growth are garbage containers, food storage areas, upholstery, and wallpaper. Molds also commonly grow in damp areas such as basements, shower curtains, window moldings and window air conditioners.

Indoor allergens that can be remediated by methods of preferred embodiments include dust mites. Dust mites are the major source of allergic reaction to household dust. They thrive on shed human skin and are most commonly found in bedrooms, where skin cells are abundant. Preventive measures include frequently laundering bed linens in hot water and removing carpets from the room. In some cases, homeowners might have to encase the bed mattress, box springs, and pillows in vinyl covers. Other allergens of animal origin include skin scales shed from humans and animals. Commonly called dander, these are another major allergen. Dander from such animals as cats, dogs, horses and cows can infest a home even if the animal has never been inside. Rodent urine from mice, rats, and guinea pigs is another allergen. Cockroach-derived allergens come from the insect's discarded skins. As the skins disintegrate over time, they become airborne and are inhaled.

Tobacco smoke, engine exhaust, and similar allergens and odors can be abated by methods of preferred embodiments, as can volatile organic compounds from sources such as household products including paints, paint strippers, and other solvents; wood preservatives; aerosol sprays; cleansers and disinfectants; moth repellents and air fresheners; stored fuels and automotive products; hobby supplies; dry-cleaned clothing, and the like. VOCs include organic solvents, certain paint additives, aerosol spray can propellants, fuels (such as gasoline, and kerosene), petroleum distillates, dry cleaning products and many other industrial and consumer products ranging from office supplies to building materials. VOCs are also naturally emitted by a number of plants and trees. Some of the more common VOCs include ammonia, ethyl acetate, methyl propyl ketone, acetic acid, ethyl alcohol, methylene chloride, acetone, ethyl chloride, n-propyl chloride, acetylene, ethyl cyanide, nitroethane, amyl alcohol, ethyl formate, nitromethane, benzene, ethyl propionate, pentylamine, butane, ethylene, pentylene, butyl alcohol, ethylene oxide, propane, butyl formate, formaldehyde, propionaldehyde, butylamine, formic acid, propyl alcohol, butylene,

heptane, isopropyl chloride, carbon tetrachloride, hexane, propyl cyanide, chloro benzene, isobutane, propyl formate, carbon monoxide, hexyl alcohol, propylamine, chlorocyclohexane, hydrogen gas, propylene, chloroform, hydrogen sulfide, tertiary butyl alcohol, cyclohexane, isopropyl acetate, tetrachloroethylene, cylohexene, methane, toluene, 1-dichloroethane, methyl alcohol, 1,1,2-trichloroethane, 1,2-dichloroethane, methyl chloride, trichlorethylene, diethyl ketone, methyl chloroform, triethylamine, diethylamine, methyl cyanide, xylene, ethane, and methyl ethyl ketone.

Odors that may be abated include skunk odors, urine, pet odors, and the like.

It is generally preferred to subject the substance to be remediated to ozone at the preferred concentrations discussed below, generally 2 to 5 ppm, and adjust the length of treatment as necessary to ensure satisfactory kill and/or neutralization levels. Serious mold infestations are generally the most resistant substance to remediate. Treatment times of 1, 2, 3, 4, 5, 6, 12, 24, 48 or more hours can be employed to ensure penetration of ozone throughout the entire mass of a serious infestation and achieve a 100% kill and neutralization. A treatment time of 2 to 3 hours in the methods of preferred embodiments is generally effective in abating serious mold infestations. However, an individual mold spore is generally killed and neutralized within minutes. Protein based allergens are generally neutralized within minutes. Bacteria are generally killed after an exposure time of minutes or less. Viruses are generally killed after an exposure of less than a minute, typically after exposure times as short as several seconds. Certain molds, bacteria, allergens, and viruses can be more resistant to ozone treatments than others. For example, anthrax spores have a hard coating that is preferably "softened up" by exposure to humidity prior to ozone treatment to ensure that all spores are destroyed by a subsequent ozone treatment. See, e.g., R. G. Rice, Ozone Science and Engineering, Vol. 24, pp. 151-158 (2002). In methods of preferred embodiments, it is generally preferred to employ treatment times of 2 to 3 hours, since such times are generally satisfactory for abating a mold infestation, and well exceed the lower limit of treatment time for substances such as protein-based allergens, bacteria, and viruses. However, when it is desired to abate a particularly virulent pathogen, such as anthrax, it can be desired to employ a treatment time over 3 hours, for example, a treatment having a duration of 5, 6, 7, 8, 9, 10, 11, 12, 16, 20, 24, 28, 32, 36, 40, 44, 48 hours or more.

The methods of preferred embodiments are generally preferred for abating substances that are sourced indoors, for example, a mold infestation, dander from a companion animal living in a house, tobacco smoke, volatile organic compounds from newly installed carpeting or freshly painted walls, and the like. Substances from outside sources, such as pollen, automobile or diesel exhaust, and the like, can also be treated using methods of preferred embodiments, but recurring treatments can be necessary as such substances reenter the interior space from outside.

Areas and Materials that can be Treated

Any interior or contained space is amenable to treatment by methods of the preferred embodiments. For example, single family homes, apartment buildings, office buildings, schools, hospitals, post offices, locker rooms, ships, trains, buses, airplanes, trucks, recreational vehicles, mobile homes, manufactured houses, cargo containers, and the like are particularly well-suited to treatment. The methods are particularly well suited for use in newly constructed homes, buildings, vehicles, and the like, which generally contain substantial quantities of VOC sources, such as newly-installed carpeting and flooring, fresh paint, adhesives, and the like. Larger enclosed spaces, such as warehouses, barns, chicken houses, and other buildings housing farm animals, grain elevators, factories, hangars, subway systems, air terminals, and the like, can also be treated provided that the preferred levels of ozone, temperature, and humidity can be attained. In certain embodiments, rather than seal and treat the entire volume of enclosed space, the space can be partitioned so as to maintain the preferred levels of ozone, temperature, and humidity in areas adjacent to those to be treated. For example, plastic sheeting can be draped over a floor or wall to be treated so as to contain the ozone and humidity and maintain the temperature adjacent to the treated area.

The methods of preferred embodiments can also be employed to treat materials. Materials that can be treated include any materials that can tolerate exposure to the ozone, humidity, and temperature conditions of preferred embodiments without suffering damage. For example, clothing, bedding and linens, rugs, mail, packages, documents, furniture, food items, agricultural products such as seeds, grains, cut flowers, produce, fruits vegetables, and live plants, containers and packaging materials, and the like. A suitable chamber can be constructed that can be sealed to maintain conditions of ozone concentration, humidity and temperature at preferred levels, and the material placed inside that chamber and subjected to treatment. In an automated process, materials can be moved through an airlock and into the chamber for treatment for a suitable time period, then moved out of the chamber through another airlock. Such automated processes can be particularly well suited for the decontamination of large volumes of mail for pathogens such as anthrax, or the decontamination of animal carcasses or meat products (beef, pork, poultry, seafood, and the like) for pathogens such as salmonella or e. coli. If the treatment chamber is of sufficient size, vehicles such as passenger cars or trucks hauling various cargo, rail cars, and the like can be treated therein.

In another embodiment, it can be preferred to subject a room or space to periodic decontamination, such as a surgical suite in a hospital, a treatment or waiting room in a clinic, a kitchen or a restaurant, a bar or nightclub, a theater, a bingo hall, a meat processing area of a grocery store, or the like. In such embodiments, it is generally preferred to permanently install equipment in a location adjacent to the space to be treated. Such equipment can include a control unit, security devices, an oxygen concentrator, an ozone generator, a humidifier, a heater and/or air

conditioner, and a ventilation unit. Prior to treatment at a convenient time (for example, after work hours), the space is scanned to ensure that no personnel are present in the room. Motion detectors, heat detectors, video cameras and the like can be suitable for such purposes. Once the space has been confirmed to contain no personnel, a lock down procedure is instituted to prevent anyone from entering the space during the treatment and to maintain conditions within the space. Treatment is then conducted according to preferred embodiments. After ozone levels have dropped to acceptable levels, the space is then unlocked. If it is necessary to reduce ozone levels to acceptable levels in rapid fashion, ozone destruct units can be employed. A computer can be employed to control the lockdown and treatment process, as well as the treatment schedule.

Assessment of Conditions

In preferred embodiments, the method typically involves an assessment of conditions in the premises, e.g., pathogen, allergen, or gas levels, followed by treatment with ozone. An assessment is typically conducted to discover if a premises (e.g., house, office building, boat, and the like) has a pathogen, allergen, or other problem that can be eliminated by using the abatement methods of preferred embodiments. If it is determined that the problem can be effectively eliminated, abatement can be conducted. It is also recommended that the underlying problem responsible for the mold infestation be identified and eliminated, so as to prevent future infestations. As part of the assessment, mold tests, e.g., tests for specific types of mold can be conducted. Other testing can include tests for VOCs, tests for allergens, tests for pathogens, and the like. Ambient conditions, including temperature and relative humidity, the size of the area to be treated (square footage, volume), can also be measured. During the assessment process, it is preferred to wear appropriate protective gear, e.g., respirators, ear plugs, gloves, foot coverings, clothing coverings, goggles, and the like. For example, when dealing with an extensive infestation of particularly toxic mold, it is generally preferred to wear full hazardous material protective gear. In situations wherein the premises are subject to odors that are unpleasant but not otherwise harmful, a respirator or no protection at all can be sufficient.

While assessments are typically conducted, in certain embodiments an assessment may not be necessary. For example, when an obvious mold infestation is present, when elimination of odors or allergens is the major impetus behind the treatment, or when the premises are treated on a periodic basis for chronic conditions such as asthma triggered by dust mites, the treatment can be initiated without performing any prior assessment.

Preparations Before Treatment

Before commencing an abatement process or other process according to preferred embodiments, it is preferred to determine the area or volume of the premises to be treated such that the target dosage the quantity and type of treatment materials and equipment that is sufficient to complete the abatement process can be determined.

It is preferred to meet with the owner (or occupier) of the building before commencing the abatement process. During the meeting, the process can be explained and the owner can assist in preparations for the abatement process. For example, all individuals, unless provided with appropriate protective gear, are instructed to leave the premises for the duration of the abatement process. Any animals, such as pets, are removed from the premises, and it is preferred to remove plants. It is not necessary to remove fish. Problem areas can be identified for treatment, along with areas that may not be amenable to treatment by the methods of preferred embodiments, or areas wherein an infestation can reoccur if the conditions contributing to mold growth are not eliminated. Areas not amenable to the preferred methods, due to either the location and/or extent of the infestation, can necessitate more extensive treatment or remediation steps, such as those employed to remove and/or dispose of toxic waste, e.g., procedures similar to those used in asbestos abatement.

Internet enabled Decontamination System

After any assessment, including identification of areas for abatement, and/or preparation, such as removing occupants, animals, and plants from the premises, has been completed, the equipment utilized in the mold abatement or other treatment process can be put in place. Such equipment can include, but is not limited to, oxygen concentrators, ozonators, humidifiers, dehumidifiers, portable power generators, air conditioners, air compressors, vacuum systems, fans, sensors, recorders, computers, communication devices, and the like.

Any suitable method or apparatus can be used to generate or provide ozone. Commercially available ozone generators with relatively low output and based on either ultraviolet or corona discharge technology are suitable for use in preferred embodiments. One drawback associated with commercially available generators can include the formation of harmful nitrogen oxides along with the ozone. Particularly preferred, however, is ozone generating equipment that delivers substantially pure (i.e., minimal amounts of nitrogen oxides produced) or pure ozone.

In a preferred embodiment, an oxygen concentrator is employed to deliver pure oxygen to the ozone generator or generators used. Oxygen concentrators are typically heavy, requiring them to be moved about on a cart to prevent worker injury. Therefore, the oxygen concentrator can be maintained in a convenient location, such as in a van or on a truck used to transport equipment utilized in the treatment process, and the pure oxygen is then delivered from a location to any number of ozone generators in remote locations via piping. In other embodiments, such as residential treatment, it can be desirable to have all equipment, including the oxygen concentrator, placed within the dwelling during the treatment process. In an industrial setting or hospital setting wherein treatments are administered on a regular basis, it can be preferable to permanently install the oxygen concentrator.

In embodiments where the oxygen concentrator is to be placed in the space being treated, the oxygen concentrator is typically enclosed within an environmentally sealed box on a cart. This arrangement provides a protective environment for an optional computer system that can be associated with the oxygen concentrator. The computer system can perform any number of functions. First, it can monitor the entire ozone treatment system, including ozone generators, fans, heaters, air conditioners, power supplies, humidifiers, dehumidifiers, monitoring devices, and the like, to ensure that all components are working correctly. Second, it can communicate via radio or other signals (wireless) or via a communication line (wire or fiber optic) with remotely located equipment including ozone generators as well as sensors monitoring ozone concentrations, humidity and temperature. With this information, the computer can control ozone dosage to that indicated by research data covering target dosages for any given situation. The target dosage is typically selected via a look-up table stored in the computer's memory or storage unit that provides optimal ozone dosages for a particular combination of humidity, temperature, and condition being treated. As a further adjunct, humidifiers or dehumidifiers can preferably be connected to the system, permitting the control of ambient humidity levels.

An additional function of the computer can include communicating with the technician performing the treatment and a remote office location via a combination of cell phone and Internet technology. Each system treatment system can have its own Internet address and communication can be established with the system from anywhere in the world as long as the system is in range of a cell phone tower. Alternatively, the system can be connected to an existing phone line or internet connection in the premises to be treated, permitting access to the internet, or dial-up access to a secure computer system in the remote office location.

This equipment design allows the equipment to be left in the spaces being decontaminated. The equipment is preferably constructed of or encased in materials that resist the corrosiveness of ozone. The system can include any or all of the above-mentioned equipment, and can be fully or partially computerized, or not computerized at all. For example, in certain embodiments a 'dumb' cart containing only the oxygen concentrator and air compressor can be preferred, and sensing and control of ozone and humidity levels and/or temperature levels can be done manually by a technician. In other embodiments, the same equipment but with added sensor communication and ozone/humidity control can be preferred. In other embodiments, and Internet or remote computer connection can be desired.

Power to the system can be provided from a dedicated generator or battery, or the system can utilize existing utility outlets in the premises to be treated.

In a preferred embodiment suitable for use in typical residential settings, the system features include the following: cart mounted, environmentally sealed case containing oxygen concentrator, computer, ozone destruct unit, heat exchanger, air compressor and cell phone

communication unit; up to 5 hose reels and holders for oxygen distribution hoses; up to 5 ozone generation units with ozone sensors; up to 5 humidifiers and humidity sensors; up to 5 radio wave send/receive units.

The environmentally sealed case on the cart provides a protective atmosphere for a computer system as described above. The oxygen concentrator housed within the cart case generates and supplies highly concentrated oxygen to the remotely located ozone generators. The cart mounted reels preferably hold up to 100 feet of ¼ inch vinyl tubing which carries the concentrated oxygen to the ozone generators strategically located throughout the premises being decontaminated. Any suitable tubing can be used, provided it is substantially inert to ozone or oxidation, such as stainless steel tubing, inert plastic tubing, or the like. To prevent premature failure due to the corrosive properties of ozone, only non-ozonated air can be used to supply the oxygen concentrator. An ozone destruct unit is preferably mounted in the concentrator's inlet air supply. This unit eliminates the ozone in the concentrator's air supply and greatly prolongs the life of the unit. As further protection, the cart case can house a heat exchanger to ensure that temperatures within the unit remain below the temperature specification limits set by the concentrator's manufacturer.

As previously mentioned, sensors mounted on the ozone generators will detect ozone, humidity and temperature levels. Ozone generation will be regulated according to the required target dosages for the particular problem being treated. Dosage tables generated by laboratory experimentation and further adapted through field-testing are used to determine optimal ozone levels. These dosage tables are stored in the computer and used to calculate the ozone levels, humidity and time required to complete specific decontamination tasks. While it is generally preferred to employ a computer to determine the proper ozone, humidity, and temperature levels, any suitable method can be employed. For example, manual calculations can be performed, or a printed look-up table can be employed. An advantage to using a computer is that levels can be rapidly determined and adjusted as needed if ambient conditions change over the course of treatment. Changes in dosages over time can also be conveniently tracked. Figure 1 provides a schematic of a preferred ozone generator and humidifier system capable of delivering ozone at a rate of 60 g/hour.

In preferred embodiments, operation support is provided via several systems, including technician training, providing equipment, delivering treatment, providing technical data, and maintaining customer and technical databases. Technician training typically includes detail on how the service is performed, gives some detail on ozone, ozone generators, sensors etc., with a strong emphasis on safety; training in all aspects of sales and customer relations; specific details on equipment operation, sensors, safe operation and maintenance of vehicles, and the like, as well as more detail on the chemistry behind the process; legal, moral and ethical aspects of dealing with

customers and representing the company; detailed explanation of existing sales and marketing programs and how the technicians are involved in these programs; functional aspects of the sales and operations databases as well as efficient scheduling; business training for those who may, in the future, be operating a central office location; and details on accounting, legal, personnel management, and other responsibilities.

Equipment for residential and small commercial treatment typically includes fully equipped trucks or vans. Each truck or van is preferably equipped with sufficient ozone generating equipment to service 2 to 4 jobs per day, depending upon the size of the premises and the contaminant involved. The trucks and vans are equipped with all necessary safety gear to ensure that neither the technicians nor the customers are endangered in any way. The trucks and vans also have small coolers in which to transport samples (e.g., mold spores) and a laptop computer equipped with the appropriate software and which is updated daily with the appropriate work orders and customer information. Once at the job site, the technicians use the laptop computers to collect any job-related information desired, including, but not limited to, volume and/or area treated, ozone concentration levels, temperature, humidity, customer comments, technician comments, and the like. The laptops can be directly connected to a main computer system through the Internet or through landlines. This allows automatic updates of databases, immediate notification of scheduling changes, and updated customer information as well as identification of the current location of the service truck.

Incoming calls from prospective customers are preferably managed in a highly professional manner. Standardized phone protocol is utilized, emphasizing courtesy while obtaining all pertinent information as quickly as possible. When necessary, the call center can provide a description of the service as well as respond to a host of frequently asked questions (FAQ's). The first image of the company is the courtesy and professionalism of the voice on the line. Telephone closing techniques as known in the art can be used when appropriate by company representatives.

In certain preferred embodiments, lead development information is collected and loaded into the company's sales and marketing database. Any suitable database software can be used, however, it is preferred that the software be Internet compatible, i.e., the database can be updated and/or modified via the Internet. In a preferred embodiment, GoldMine™ Version 5:5, available from GoldMine Software Corporation a database management system on its own network. The program accumulates contact information, for the purposes of tracking contacts, their histories, and pending actions. It is accessible on-site or from remote locations. The system is also used to produce automated direct marketing campaigns. The system is fully capable of expanding to accommodate business growth and is integrated with the technical database software that has been installed. The GoldMine™ database is preferably customized to better function as a technical database for use in the preferred embodiments. It can be customized to produce work orders,

invoices and to accumulate each job's technical data including tests results, treatment data and customer reactions. This software allows a database to be built on efficacy of the process in different conditions and with different types of contaminants.

Any suitable computer network can be employed in those embodiments wherein a computer is desirable for some aspect of the treatment or subsequent data storage or analysis. A computer network based on a T1 backbone and server running MS 2000 Server software available from Microsoft Corporation is utilized in a preferred embodiment. The system has full security and is set up as a Virtual Private Network (VPN) allowing authorized users access from any Internet connection. This also allows the technicians the capability of accessing the network from home or any other location with Internet access.

Pretreatment

In certain embodiments, it can be desirable to pretreat the area prior to subjecting the area to ozone treatment. A preferred pretreatment involves subjecting the area to be treated with humidity. Certain pathogens, such as mold spores and anthrax, are resistant to conventional ozone treatment. The anthrax bacterium, for example, possesses a hard shell that resists penetration by ozone. By subjecting anthrax to humidity prior to ozone treatment, the ozone is better able to penetrate the microorganism and destroy it. Likewise, mold spores are resistant to penetration by ozone, but can be made more amenable to treatment by first subjecting them to humidity. Treatment of VOCs is also facilitated by humidity. Ozone reacts with atmospheric water to produce reactive hydroxyl groups, which then react with certain VOCs to yield less harmful or harmless substances.

When the material to be treated includes molds, a pretreatment consisting of exposure to a relative humidity of 70% to 85% is typically employed. Typical pretreatment exposure times of 10 minutes, 15 minutes, 30 minutes 45 minutes, 1 hour, 1.5 hours, 2 hours, 2.5 hours, 3 hours, 4 hours, or more can be employed, depending upon the substances to be abated and the nature of the space or material to be abated. In residential mold remediation, pretreatment times of from 30 minutes to 2 hours are generally preferred. In decontaminating a material infested with anthrax, pretreatment times of from 12 hours to 24 hours are generally preferred.

Abatement of Living and Working Spaces

If the area to be treated has an air duct system (e.g., heating or heating/air conditioning system), it is preferred to position one or more ozonators adjacent to the return air inlet. Typically, for treating volumes of 25,000 cu. ft. or less, it is preferred that at least 10 g/hr of ozone is drawn into each air inlet. However, in certain embodiments satisfactory results can be obtained at a lower level of ozone generation, for example, at about 0.1, 0.5, 1, 2, 3, 4, 5, 6, 7, 8, or 9 or more g/hr. Likewise, in certain embodiments a higher level of ozone generation can be preferred, for example, about 10, 11, 12, 13, 14, 15, 20, 25, 30, 40, 50, 60, 70, 80, 90, or 100 or more g/hr. Commercially

available ozonators are available in a variety of sizes. Size is generally reported in terms of ozone output in grams/hour. It is generally preferred to locate mid-sized (e.g., 6 or 10 gm/hr) ozonators in larger areas, e.g., living room, kitchen/family room, open stairways, open office spaces, and the like. Smaller ozone generators (e.g., 1-5 gm/hr) are preferably situated in small or closed-in areas, or areas that are unlikely to get circulating air, for example, basements, storage areas, and the like. Generally dosage calculations show that ozone generators that are capable of generating 20 g/hr of ozone are sufficient to treat a 2,000 sq. ft. house with forced air ducting. More ozone can be preferred for a house without forced air ducting. Typically, dosage calculations show that one gram of ozone per hour is preferably generated for every 1000 cu. ft. of area to be treated. More or less can be required depending on humidity, temperature, and specific condition being treated. Therefore, a 1 gm/hr ozonator generally covers a 125 sq. ft. area with 8 ft. ceilings. In certain embodiments, however, a greater or lesser number of ozone generators, or ozone generators of different sizes can be preferred. Determination of the amount of ozone required is made according to the target dosage found in the dosage tables relating the ozone concentration, humidity and temperature to the problem be treated such as mold, allergens, pathogens or VOCs.

After the ozone generators are situated and turned on, the forced air system is then turned on to circulate the air. It is generally preferred that no heating or cooling of the air is conducted, however, in certain embodiments it can be preferred to heat or cool the air so as to obtain optimal abatement results.

Humidity has been observed to be a significant factor in the kill rate of allergens and pathogens. In general, the higher the humidity, the faster the ozone kills the pathogen or destroys the allergen. While not wishing to be bound to any particular theory or mechanism, it is believed that the ozone is solubilized in the water vapor, which serves as an "ozone delivery device" to the pathogen to be killed, thereby increasing the effectiveness of the process. Generally, it is preferred that the relative humidity in the premises to be treated be at least 30% or more, preferably the relative humidity is at least 40%, 45%, 50%, 55%, or 60% or more, more preferably the relatively humidity is from 65% to about 70%, 75%, 80%, 85%, or 90% and most preferably the relative humidity is from about 70% to about 90% or 95%. Relative humidities greater than 95%, especially relative humidities of 100%, are generally not preferred due to the risk of condensation, which can lead to bleaching of sensitive materials. However, in certain embodiments relative humidities greater than 95% can be acceptable if sensitive materials are not a concern.

In coastal areas, ambient humidity can provide optimal results. However, in desert areas or under low humidity conditions (e.g., winter in northern areas of the United States), it can be preferred to increase the humidity via one or more humidifiers so as to achieve optimal results. Once treatment is completed, it can be desired to employ one or more dehumidifiers to rapidly restore the ambient humidity to the treated premises, if the premises are humidity-controlled. In

certain instances, it may not be feasible to humidify the area to be treated. For example, the area can contain humidity-sensitive materials (e.g., antiques, rare books, old documents, fragile textiles or wallpaper, oxidizable metals, and the like). In those instances, treatment can be conducted under ambient humidity conditions, but the duration of the ozone treatment can be extended to ensure satisfactory results.

Temperature levels also correlate with the effectiveness of the treatment method in killing mold. Generally, as temperature increases, the effectiveness of the treatment increases. However the amount of ozone required to achieve and maintain the target dosage also increases as the ozone more readily reverts back to oxygen at higher temperatures (i.e., ozone exhibits a shorter half life at higher temperatures). Generally, it is preferred to conduct the treatment at a temperature typically considered a "room temperature," namely about 17.7°C (64°F), 18.3°C (65°F), 18.8°C (66°F), 19.4°C (67°F), 20°C (68°F), 20.5°C (69°F), or 21.1°C (70°F) up to about 21.6°C (71°F), 22.2°C (72°F), 22.7°C (73°F), 23.3°C (74°F), 23.8°C (75°F), 24.4°C (76°F), 25°C (77°F), 25.5°C (78°F), 26.1°C (79°F), 26.6°C (80°F), 27.2°C (81°F), 27.7°C (82°F), 28.3°C (83°F), 28.8°C (84°F), or 29.4°C (85°F). In most residential and commercial settings, the ambient temperature falls within this range. However, if the premises to be treated is not equipped with heating or air conditioning, it can be preferred to adjust the interior temperature prior to initiating treatment, or to control the temperature at a pre-selected level during treatment. When the ambient temperature is high and the structure to be treated is not equipped with air conditioning, an air conditioning unit can be provided as part of the equipment system and used to cool the temperature, e.g., down to below 29.4°C (85°F). Cooling the interior to below 17.7°C (64°F) generally results in only an incremental reduction in the rate of ozone decomposition. Thus, it is generally not preferred to cool the interior below this temperature. If the ambient temperature is substantially below 17.7°C (64°F), it is generally preferred to heat the interior. In certain conditions, the temperature in the structure to be treated can be controlled to a pre-selected temperature, for example, a cold storage locker or a room containing equipment or machinery that must be operated at an elevated or reduced temperature. Under such conditions, the treatment is preferably conducted at ambient temperature and the ozone level and/or humidity is adjusted to achieve optimum results. In certain embodiments, however, it can be desirable to treat an area at temperatures outside of those typically considered ambient temperatures. For example, a refrigerated unit maintained at a temperature above 0°C (32°F) can be satisfactorily treated by adjusting the humidity and ozone levels. Generally, ozone levels are increased at low temperatures. However, lower ozone levels of 2 to 5 ppm can be employed in conjunction with a longer treatment time.

Ozone levels of 2 to 5 ppm are generally preferred for treating mold and other substances. However, in certain embodiments it can be preferred to employ ozone levels of 1.9, 1.8, 1.7, 1.6,

1.5, 1.4, 1.3, 1.2, 1.1, 1.0, 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2 ppm or less. In other embodiments, ozone levels of 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 25, 30, 35, 40, 45, 50 ppm or more can be preferred. At optimal humidity and temperature levels, a longer treatment time is preferably employed at reduced ozone levels and a shorter treatment time is preferably employed at higher levels so as to ensure a satisfactory kill and/or neutralization level.

In terms of the optimal combination of ozone level, temperature, and humidity, it is generally preferred to conduct a treatment at a temperature of about 21.1°C (70°F), a relative humidity of about 85%, and an ozone level of about 20 ppm. Under these conditions, the length of time required to achieve a 100% kill for mold spores is minimized. For in a typical residential setting, a 100% kill can be achieved in about 3 hours or less. Figure 2 provides a graph depicting optimal conditions of ozone concentration, treatment times, and humidity at a temperature of 5°C (41°F). Figure 3 provides a graph depicting optimal conditions of ozone concentration, treatment times, and humidity at a temperature of 15°C (59°F). Figure 4 provides a graph depicting optimal conditions of ozone concentration, treatment times, and humidity at a temperature of 25°C (77°F). While a 100 % kill and/or neutralization is generally preferred when treating any pathogen, allergen, or VOC according to the methods of preferred embodiments, in certain embodiments satisfactory results can include only a partial kill or neutralization.

When the temperature ranges from about 15.5°C (60°F) to about 26.6°C (80°F), i.e., interior temperatures typically observed for residential and commercial buildings, it is preferred that the relative humidity be in the range of about 70% to about 85%, and the ozone levels be in the range of about 2 ppm to about 5 ppm. Under these conditions, the optimal time to achieve a 100% kill is typically about 1 to about 3 hours.

For structures situated in high humidity environments, e.g., the coastline, the Midwest during summer, and the like, wherein the relative humidity ranges from about 85% to about 95% and ambient temperatures range from about 21.1°C (70°F) to about 32.2°C (90°F), lower ozone levels can be employed. Under these conditions, the optimal time to achieve a 100% kill is typically about 1 to about 3 hours.

For structures situated in low humidity environments, e.g., desert communities, and the like, wherein the relative humidity ranges from about 5% to about 20% and ambient temperatures range from about 23.8°C (75°F) to about 37.7°C (100°F), it is preferred that the relative humidity is raised via the use of a humidifier or other suitable method to from about 70% to about 85% before beginning treatment and that the ozone levels are in the range of about 2 ppm to about 5 ppm. Under these conditions, the optimal time to achieve a 100% kill and/or neutralization is typically about 1 to about 3 hours.

In commercial and residential settings, and the like it is preferred to open all closet and cupboard doors, and to move items stored in cupboards and closets to facilitate air circulation. Doors, windows, fireplace dampers, and other air egresses are preferably closed.

In residential settings, if dust mites are problematic, it is preferred that all linens be taken off beds and washed in 60°C (140°F) water. Mattresses are typically removed from the box spring and leaned up against the box spring so as to facilitate air circulation around the mattress. If feasible, blankets, pillows, and bed spreads are preferably placed in a manner that allows satisfactory air circulation. Exhaust fans, e.g., in the kitchen, bathroom, and the like, are turned on, which helps ensure that ozonated air reaches the outlet ducting of these areas. If such fans have a variable speed, they are preferably operated at their lowest possible level to reduce the amount of ozone that will evacuated while at the same time ensuring that the vent system is decontaminated.

Before the ozonators are activated, humidifiers may be employed to achieve required relative humidity levels if necessary according to the target dosage. Once target humidity levels are achieved, the area can be evacuated of any nonessential personnel. For those individuals remaining in the premises, a respirator (and goggles if the respirator is not a full-face respirator) is preferably in place before turning on the ozonators. The ozonators are typically turned on starting with the most remote areas of the premises and finishing with the heating and air conditioning inlet or inlets last. After the ozonators have operated for a short time period, typically about ten minutes, it is preferred to test and record ozone, temperature, and humidity levels. For non-automated ozonators this will require reentering the premises and taking the necessary readings. Once the ozone and humidity levels have reached target dosage levels, typically at least about 2 to 5 ppm ozone and 75-90% RH, effective treatment has begun, and the premises can be left closed for the duration of the treatment. Although 2 to 5 ppm ozone is generally preferred, in other embodiments a higher or lower ozone level can be desirable, e.g., less than 0.1, 0.5, 1, 2 ppm ozone up to about 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 500, 1000, 2000, 3000, 4000, 5000 ppm ozone or more. If the infestation is particularly extensive or the mold to be abated particularly toxic, higher ozone levels can be preferred. To prevent injury, all doors and other possible entrances to the building are preferably locked and caution signs placed the entrances.

Humidity, temperature, and ozone concentration readings are typically recorded in each room during the course of the treatment procedure. These recordings can be obtained automatically, e.g., by stand-alone recorders in the rooms or by the ozone generator equipped with measuring devices. Alternatively, the recordings can be obtained manually at pre-selected intervals.

Treatment is typically continued for up to 48 hours depending on the target dosage which relates temperature, humidity, ozone concentration, and condition being treated to treatment time. After treatment is completed, the ozonators are turned off and ozonated air can be evacuated from

the premises if immediate occupancy is desired. Alternatively the ozone can be left to degrade back to oxygen if immediate occupancy is not required. If immediate occupancy is desired fans are typically placed in one or more doorways and/or windows to blow ozonated air out of the premises. High volume fans (9400 c.f.m.) are generally preferred for residential applications, however fans capable of moving more air or less air than 9400 c.f.m. can also be suitable for use. The evacuation fans are typically operated for 30 minutes, then ozone levels are tested, especially in areas where circulation from the fans is lowest, such as bedrooms, basement, and the like. Depending upon the circulation efficiency, longer or shorter operation times can be preferred.

As an alternative to the use of evacuation fans, the premises can remain closed and the ozone can dissipate and/or decompose to safe levels without taking active steps to remove ozonated air from the premises. In an enclosed space with poor air circulation, ozone levels will typically return to ambient levels after about 6 hours. However, it is generally preferred to take active measures to evacuate ozonated air such that the delay in reoccupying the premises is minimized.

Ozone levels are periodically tested until a pre-selected ozone level at which it is safe to reoccupy the building is achieved. A self contained breathing apparatus or respirator is preferably employed for testing until a level of 0.1 ppm ozone, 0.05 ppm ozone, or less is recorded, or until levels of ozone similar to outside ambient levels are achieved, if ambient levels are higher than 0.1 or 0.5 ppm. An ozone level of 0.05 ppm has been determined by the FDA to be a safe level for continuous exposure. An ozone level of 0.1 has been determined by OSHA to be safe for exposure times of up to 8 hours. Once the level drops below 0.05 ppm or outside ambient levels, the treated area is typically safe for reoccupation by people, animals, and plants and treatment is complete. If level is not below 0.05 ppm in all areas, circulation by fans is continued until this level is reached. While 0.05 ppm is the preferred level deemed safe for reoccupation, in certain embodiments it can be preferred that a lower level be attained, e.g., a level characteristic of ambient ozone levels prior to treatment. Alternatively, a higher level of ozone can be acceptable in certain embodiments.

Ozone levels can be tested using commercially available instrumentation, such as that manufactured by Eco Sensors of Santa Fe, NM. When testing for current ozone levels, the instrument is used in accordance with the manufacturer's instructions. These typically include allowing adequate warm up time (generally at least 5 minutes), not blocking the air flow into the instrument while testing, making all measurements in still air as moving air can affect the readings, keeping the instrument away from the body as body odors can bias the reading, not using the instrument to take measurements directly from the outlet of the ozonators which can result in incorrect readings and/or damage to the instrument.

After the premises has been deemed safe for reoccupation, doors and windows can be unlocked, caution signs can be removed, and all equipment, including fans, ozonators, and humidifiers can be removed from the premises.

It is noted that in the case of allergens and pathogens, treatment does not remove the allergen or pathogen from the treated area. In the case of a pathogen, such as mold spores, the organism is killed. If the pathogen has an ability to produce an allergic reaction, this ability is also neutralized. In the case of an allergen such as animal dander or dust mite feces, the protein causing the allergic reaction is neutralized by the ozone treatment such that it is unable to cause an allergic reaction. A subsequent cleaning step to remove the dead organism or deactivated allergen can be desirable in certain embodiments, but is not necessary.

Carpet Cleaning

In many cases of mold infestation, carpet and padding can be infested as well. Such infestation is typically dealt with by removing the affected materials from the premises. In certain aspects of the preferred embodiments, the treatment process described above is supplemented with *in situ* carpet cleaning. By cleaning the carpeting *in situ*, the expense and inconvenience of removing and replacing the carpeting can be avoided.

The carpeting is preferably cleaned by applying a cleaning solution under high pressure, i.e., 200 to 1000 psi or higher, to the affected carpet. The preferred pressures are higher than those typically utilized in commercial carpet cleaning equipment to ensure effective penetration of the cleaning solution to the underside of the carpet, where mold typically grows. Without effective penetration to the underside of the carpet, all of the mold may not be killed and the infestation can reoccur.

The cleaning solution can include ozonated water, or water containing other disinfectants as are known in the art. In certain embodiments it can be preferred to use a non-aqueous cleaning solution, or high pressure steam. However, for most embodiments aqueous cleaning solutions at room temperature or elevated temperatures typically used for laundering textiles, e.g., (60°C) 140°F, are preferred.

In a particularly preferred embodiment, the method utilizes a portable cleaning workstation manufactured by CFR Corporation of Fort Worth, Texas. CFR's cleaning workstations do not saturate the carpet with water and chemicals to remove the soils and residue like conventional extractors. Instead, the cleaning solution is atomized to create a high-powered continuous flow that in many cases removes up to 93% of the cleaning solution. The cleaning solution is recycled and filtered to reduce the dumping and refilling normally associated with carpet cleaning. This increased cleaning efficiency, combined with fast drying times, reduces cleaning costs while improving indoor air quality. The workstations utilize patented air induction tools to atomize high velocity solution at 200-1000 p.s.i. to "scrub" each individual fiber and simultaneously recover this solution to prevent over-wetting. Carpeting, upholstery and fabric partitions can be cleaned using the workstations. The workstations offer better performance than conventional extractors do.

Particularly preferred are the CFR PERFORMA OZ™ and CFR PERFORMA ELITE OZ™ ozone-assisted workstations. These mid-size workstations include an ozone generator utilizing ultraviolet light, and combine fast and effective 200 p.s.i. cleaning power and performance with the fast dry times of continuous fluid control. The Performa combines traditional "pull behind" cleaning operation with patented continuous fluid control and recycling technology. An optional agitator brush is available for heavy restoration cleaning. Also preferred are the CFR ALTRA™ environmental cleaning workstations. The CFR ALTRA™ systems offer versatility in the cleaning of carpets, hard surfaces, upholstery, and modular office panels. The cleaning station's continuous flow recycling technology provides maximum cleaning power while safeguarding even the most delicate surfaces. These systems are specifically designed to handle professional cleaning jobs quickly, thoroughly and economically. The CFR ALTRA™ produces deep cleaning power, fast dry times, and high production rates. It increases cleaning productivity, improves cleaning results and reduces labor and chemical cost. Over 92% of the solution is instantly recovered. The fast-working CFR cleaning solution passes through carpet fibers at 1.25 gallons per minutes to remove stubborn soils and stains, then is almost instantly returned to the solution tank for recycling.

If a carpet or other textile, e.g., a fabric partition, in a premises to be treated is also affected by a mold infestation or contains other pathogens, allergens, or odors, it can be cleaned as described above as part of an overall treatment process. The carpet or other textile can be cleaned before, during, or after treatment of the premises via circulation of ozone in ambient air, as described above. However, it is generally preferred to clean carpet and other textiles either before or after, for optimal safety and convenience.

<u>Treatment of Interior Wall, Floor or Ceiling Spaces</u>

Mold often affects visible areas of a premises. However, mold can also affect areas that are not readily observed, such as the areas behind walls, in crawl spaces, ventilation ducts, or other enclosed areas. When the space behind a wall is subject to a mold infestation, the typical method of dealing with the infestation is to demolish and rebuild the affected area. This method suffers from serious drawbacks, including the expense of demolishing and rebuilding, properly disposing of the mold-contaminated materials, and the inconvenience associated with the demolition and construction process. A method for abating mold infestations in such areas more efficiently, cheaply, and quickly than demolition and rebuilding is therefore highly desirable.

If satisfactory air circulation can be achieved in these areas, then they are amenable to treatment according to the methods described above wherein ozone-containing air is circulated throughout the area. However, if air circulation is poor, then mold abatement or abatement of other pathogens, allergens, odors, and the like can also be achieved via certain modifications to the methods described above.

In a preferred embodiment, a method for treating the space behind a wall subject to a mold infestation is provided. The method involves forming a small hole in the wall extending into the interior space through which ozone can be pumped into the interior space. A second hole is provided at the opposite end of the wall to allow circulation of the ozonated air through the wall space. For example, ozone can be pumped into the interior space through a small hole at the base of the wall. A corresponding hole at the top of the wall is provided to allow the ozonated air to escape after circulating through the wall space. The evacuation hole at the top of the wall can be under vacuum to assist the movement of the ozone within the space. Wall spaces, especially exterior wall spaces, often contain insulation, studs, electrical outlet boxes, piping, and the like which can inhibit airflow. To facilitate airflow, ozone is introduced into the wall spaces under pressure. As an alternative, the hole used to introduce the ozone can be at the top of the wall and the evacuation hole at the bottom.

Because adequate airflow can be difficult to achieve, the concentration of ozone when introduced in the interior space during treatment is typically higher than that utilized in the method described above for circulating ozonated air in spaces where air circulates freely. Ozone levels are typically well above the 2 to 5 ppm ozone levels preferred when air circulates freely, and are preferably about 30, 40, 50, 60, 70, 80, 90, 100, 500, 1000, 2000, 3000, 4000, 5000 ppm or higher. If the infestation is particularly extensive, the mold to be abated is particularly toxic, or air circulation is particularly difficult to achieve, even higher ozone levels can be preferred. Likewise, if adequate air circulation can be achieved, lower treatment levels can provide satisfactory results. It can be preferred to supply ozone at high concentrations to one end of an enclosed space containing obstructions to airflow, and monitoring ozone levels at the opposite end of the enclosed space over time. Once an ozone concentration of 2 to 5 ppm is achieved at the opposite end of the space, then the concentration of ozone supplied can be reduced to a lower level, for example, a level sufficient to maintain the ozone concentration at the opposite end of the space at a steady 2 to 5 ppm.

In order to ensure that the correct dosage is being circulated within the wall, the air emerging from the evacuation hole is preferably tested for ozone concentration within the first hour of starting the procedure. If adequate ozone is not present then a number of steps are taken to ensure that the target dosage is achieved. First, a stud finder is employed to find any blocking cross bracing that can be hidden in the wall. If cross bracing is found, then new access and evacuation holes are placed above and below the bracing and the above and below sections are treated separately. If no bracing is found, then both the ozone pressure and vacuum are increased. If this is not successful, then the affected stud section can be opened and remediated manually.

To ensure a complete 'kill' of the mold, tests can be taken at the end of the treatment. These tests are typically accomplished by sampling the air/ozone mixture being evacuated at the

top of the wall. The air/ozone mixture is passed through a filter medium which collects mold spores. These samples are then sent to a laboratory for culturing and speciation (if required).

One of the advantages to treating the spaces behind walls using the method as described above is that the treatment can be carried out without the need for first evacuating the building. Prior to treatment, all possible egresses from the wall space are preferably sealed off, including wall outlets, light switches, and light fixtures. Ozone is typically introduced into the interior space via piping from the ozone generator. The area through which the piping enters the wall space is preferably sealed so as to minimize leakage from the wall. Piping can be inserted into the hole providing egress of gasses from inside the wall such that ozone can be vented to outside the premises. When a series of joists separate the interior space of the wall to be treated, a series of ingress and egress holes, one or more of each for each space between a set of joists, can be provided. It is especially preferred to provide holes into the wall space from the exterior of the premises, so as to minimize inconvenience to the occupants of the building and accidental ozone release via leakage around the piping.

Target dosages are typically similar to those utilized where adequate air circulation is readily achieved. After treatment, the interior spaces can be cleared of ozonated air by introducing pressurized pure air into the interior space, or by permitting the ozone to dissipate on its own. Interior and exterior walls can be treated according to the above-mentioned method. Crawlspaces, sub-floors, and attic spaces can also be treated according to the above-described method, but can also be amenable to circulation of ozonated air as in treating rooms subject to infestation. Provided that the rooms and other living or working spaces of the premises can be adequately sealed off, such treatment can be conducted without the necessity of first evacuating the building.

Pretreatment and Post-treatment for Ozone Control

After an ozone treatment is administered and ozone returns to ambient levels, a strong ozone odor can still be noticeable. If there is such an odor, it is generally associated with closets and bedrooms. While not wishing to be bound to any particular theory, it is believed that fabrics or other materials containing natural or synthetic fibers having an electrostatic charge can attract and hold ozone, slowly releasing it back into the surrounding air at noticeable levels. While a portion of the population considers ozone to have a pleasant odor, some individuals consider the odor unpleasant. Other individuals, typically those suffering from asthma, can find ozone to be an allergen. Accordingly, a method for reducing or eliminating lingering ozone or the odor associated with ozone is desirable.

Any suitable method can be employed for destroying or removing lingering ozone. For example, ultraviolet (UV) light is preferably employed. A UV light source can be brought into the space treated, and the light therefrom can be passed over the materials that are holding the ozone, such as bedding, clothes, drapes, and the like. The UV treatment is preferably conducted after

completion of the ozone treatment, most preferably as soon as detected ozone levels reach ambient levels.

Removal of ozone can also be accelerated by subjecting the interior spaces to elevated temperatures, for example, by a radiant heater or hot air blower.

In other embodiments, it can be preferred to employ ions. Depending upon the nature of the materials in the treated space, it can be desirable to employ only positive or negative ions, or to employ positive ions for a time followed by negative ions, or vice versa. Any suitable equipment for generating ions can be employed. It is generally preferred to employ an ion generator capable of producing $1\times10^{12}$ ions per second (negative or positive). Such an ion generator is generally suitable for use in rooms or spaces having an area of approximately 500 sq. ft. Alternatively, bipolar ionization can be employed. Bipolar ionization uses an alternating current to produce both positive and negative ions. Bipolar ionization utilizes a process involving association and disassociation to generate a highly reactive mixture of ionized gas consisting of atoms, molecules, and free radicals capable of creating chemical changes. There are several types of devices that can be used for this process. For HVAC applications, a non-thermal type of surface discharge reactor is preferably used. Bipolar ionization was first used commercially in 1972 in the food and meat industry in Western Europe to improve shelf life of perishable foods with limited or no mechanical refrigeration.

When the bipolar ion generator is connected to an oscilloscope, a sinusoidal waveform is observed. On one side of the waveform, the bipolar generator produces positively charged ionized gas molecules and on the other side of the waveform, the bipolar generator produces negatively charged ionized gas molecules. This is a pulsed AC system, which alternately produces negative and positively ionized gas molecules. In operation, a pulsed ion field is created in the vicinity of the bipolar generator. As air passes through the ion field, electrons in the valence shells of stable molecules receive excitation energy. As the air stream moves out of the ion field and through the air-handling unit, the electron vibrational energy permits valence electrons to overcome nuclear attraction and escape. Chemical bonds are broken in gas molecules, ionic compounds disassociate to positive and negative ions, and covalent compounds disassociate to free radicals. In the absence of a polar field, the highly unstable ions and free radicals combine to form more stable compounds.

To determine what type or types of ions are preferred for treating a space, the materials contained within the space can be classified on the basis of their place in a triboelectric series. Below is a very short triboelectric series that provides an indication of the ordering of some common materials. A material that charges positive will be the one that is closer to the positive end of the series and the material closer to the negative end will charge negatively. Accordingly, to reduce the charge on the material, ions of opposite polarity can be applied. It is the work function of the material that determines its position in the series. In general, materials with higher work

function tend to appropriate electrons from materials with lower work functions. Triboelectric series (from positive to negative): positive (+) > asbestos > glass > nylon > wool > lead > silk > aluminum > paper > cotton > steel > hard rubber > nickel & copper > brass & silver > synthetic rubber > Orlon > saran > polyethylene > Teflon > silicone rubber> negative (-). While such triboelectric series can be helpful in determining the preferred ion treatment, other factors can affect the preferred treatment. For example, real materials are seldom very pure and often have surface finishes and/or contamination that strongly influence triboelectrification. The spacing between materials on a triboseries does not allow one to predict with any confidence the magnitude of the charge separated. Many factors besides the difference in the electronic surface energy, including surface finish, electrical conductivity, and mechanical properties, can also strongly influence results.

In addition to controlling ozone odor, bipolar ionization methods can yield additional benefits, including microbiological control, control of other odors and gas phase chemicals, static control and filtration enhancement. After dissipating the ionization energy, air with a balanced electrical charge remains. In the absence of any electrical charge, submicroscopic particulates are not attracted to foreign surfaces and remain airborne and naturally buoyant. Air currents established by an efficient air distribution system displace the particulates and carry them back to the filters in the air-handling unit. Particulates that pass through the filters remain buoyant on subsequent circulation cycles and are returned to the filters for another attempt at removal. With every pass through the filters, the probability increases for removal.

It is generally preferred to employ an ion treatment during the ozone treatment. However, an ion treatment can also be conducted before or after the ozone treatment, or at any suitable time.

<u>Remediation of Norwalk Virus</u>

Interior spaces, such as in cruise ships, infected with Norwalk virus can be remediated by methods of preferred embodiments. The procedure generally preferred is as follows: Ships are generally constructed such that sections of the ship can be isolated from the remainder of the ship. These sections have independent heating, ventilating, and air conditioning systems (HVAC) as well as sealable doors providing total isolation. Humidification and ozonation equipment can be brought aboard the ship and placed within one or more of the isolatable sections. The humidifiers and ozonators can be placed near or within the air inlets of the HVAC system and all systems placed in operation. This circulates the ozone and humidity throughout the isolated section of the ship at target dosages determined to be lethal to the Norwalk and other viruses and bacteria. Once the target dosage has been achieved then the ozone can be left to decompose back to oxygen or it can be evacuated by opening the outside makeup air system to allow 100% makeup air, thereby evacuating the ozone and allowing rapid reoccupation of the treated section.

Remediation of Anthrax

Methods of preferred embodiments are suitable for use in decontaminating indoor areas or materials contaminated with anthrax. The procedure generally preferred is similar to that noted for Norwalk virus, with the exception that the area to be treated is pre-treated with humidity for a period of 12 to 24 hours at levels of humidity greater than 70%. Humidifiers are placed with the area to be treated if necessary. They are turned on and allowed to operate until such time as a level of at least 70% relative humidity is achieved. Once this level has been achieved, the pretreatment period has begun. Once the pretreatment period has been concluded, the actual treatment can be completed based on target dosages for anthrax. With regard to safety issues, significantly more stringent safety procedures are required when treating an area contaminated with anthrax or other particularly virulent pathogens. Scientifically accepted hazardous material safety procedures are followed strictly by all personnel involved in the decontamination procedure.

Example

Santa Monica House

A private residence located in Santa Monica, California was treated with ozone according to a preferred method. A full study of the "before treatment" and "after treatment" conditions in the house was conducted by an independent Indoor Air Quality specialist. The testing portion of the study consisted of taking air samples outside the house to determine background levels of contaminants and in 3 rooms within the house. These tests were conducted on Feb. 14, 2002 (before treatment) and then again on Feb. 21, 2002 (after treatment). The results of the study showed that, in the two bedrooms tested, all types of identified mold spores were reduced below that of the outdoor air (i.e., a 100% kill), while in the dining room the very high levels of *Penicillium/Aspergillus* (12,339 spores/m$^3$) were reduced by more than 99% while the levels all other fungi types were equal to or below that of the outdoor air (a 100% kill). The graphs provided in Figures 2, 3, and 4 provide a visual representation of the results obtained in the Santa Monica home's dining room, master bedroom, and second bedroom, respectively, and are typical of the results obtained using the method of the preferred embodiments.

Examples of mold levels before and after treatment according to the method of the preferred embodiments are provided in Table 1. The numbers refer to total mold count for all mold types.

Table 1

| | | **Total Mold Count (spores/m$^3$)** | |
|---|---|---|---|
| **Treatment** | **Location** | **Before** | **After** |
| | | | |
| 1 | Master Bath Skylight | 30,900 | 681 |
| 1 | Master Bath Above Shower | 526,000 | 0 |
| 1 | Family Room Ceiling | 641,000 | 0 |

| | | | |
|---|---|---|---|
| 2 | Above Shower | 672,000 | 0 |
| 2 | Bedroom / Closet Wall | 18 | 0 |
| 2 | entry Closet | 86,900 | 276 |
| 3 | Master Bedroom | 8,620 | 755 |
| 3 | Shower | 110 | 0 |
| 4 | n/a | 200 | 5 |
| 5 | Garage | 43,200 | 681 |

The preferred embodiments have been described in connection with specific embodiments thereof. It will be understood that it is capable of further modification, and this application is intended to cover any variations, uses, or adaptations of the invention following, in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practices in the art to which the invention pertains and as can be applied to the essential features hereinbefore set forth, and as fall within the scope of the invention and any equivalents thereof. All documents, including patents, literature articles, bulletins, and the like, cited herein are hereby incorporated by reference in their entirety.

WHAT IS CLAIMED IS:

1. A method for abating a pathogen, allergen, or odor, the method comprising the step of exposing the pathogen, allergen, or odor to an atmosphere comprising an ozone concentration of from about 2 ppm to about 5 ppm, a relative humidity of from about 70% to about 90%, and a temperature of from about 15°C to about 27°C for at least a time of from about 1 hour to about 3 hours, whereby the pathogen, allergen, or odor is abated.

2. The method of claim 1, wherein a pathogen is abated, the pathogen comprising a species of mold.

3. The method of claim 1, wherein a pathogen is abated, the pathogen comprising Norwalk virus.

4. The method of claim 1, wherein a pathogen is abated, the pathogen comprising anthrax.

5. The method of claim 1, wherein an allergen is abated, the allergen comprising dust mite feces.

6. The method of claim 1, wherein an allergen is abated, the allergen comprising dander.

7. The method of claim 1, wherein an allergen is abated, the allergen comprising a protein capable of inducing an allergic reaction in a human susceptible thereto.

8. The method of claim 1, wherein an allergen is abated, the allergen comprising tobacco smoke.

9. The method of claim 1, wherein an odor is abated, the odor comprising a volatile organic compound.

10. The method of claim 1, wherein an odor is abated, the odor comprising urine.

11. A method for abating a pathogen, allergen, or odor in an enclosed space in which air can circulate freely, the method comprising the steps of:

sealing the space such that conditions of ozone concentration, temperature, and relative humidity can be controlled within the space;

providing ozone to the air of the space until a concentration of at least about 2 ppm to about 5 ppm is achieved in all areas of the space;

maintaining the concentration of ozone in the air of the space at a level of about 2 ppm to about 5 ppm for at least a time of from about 1 hour to about 3 hours;

providing moisture to the air in the space until a level of relative humidity within the space reaches about 70% to about 90%; and

controlling the temperature within the space at about 15°C to about 27°C, wherein the steps of controlling the relative humidity and controlling the temperature are conducted

substantially simultaneously as the step of maintaining the concentration of ozone, whereby the pathogen, allergen, or odor is abated.

12. The method of claim 11, further comprising the steps of:

ceasing providing ozone to the air of the space; and

permitting the concentration of ozone in the air of the space to return to an ambient level.

13. The method of claim 12, further comprising the step of:

exposing a material in the space to ultraviolet light, whereby an odor associated with ozone or an allergic reaction to ozone is reduced, wherein the step is performed after ceasing providing ozone.

14. The method of claim 12, further comprising the step of:

exposing the space to a temperature above 27°C, whereby an odor associated with ozone or an allergic reaction to ozone is reduced, wherein the step is performed after ceasing providing ozone.

15. The method of claim 12, further comprising the step of:

providing ions to the space, whereby an odor associated with ozone or an allergic reaction to ozone is reduced.

16. The method of claim 15, wherein the step of providing ions is conducted before the step of maintaining the concentration of ozone.

17. The method of claim 15, wherein the step of providing ions is conducted during the step of maintaining the concentration of ozone.

18. The method of claim 15, wherein the step of providing ions is conducted after the step of maintaining the concentration of ozone.

19. The method of claim 15, wherein the ions comprise positive ions.

20. The method of claim 15, wherein the ions comprise negative ions.

21. The method of claim 15, wherein the ions comprise positive ions and negative ions.

22. The method of claim 15, wherein the ions are generated by a bipolar ion generator employing a pulsed AC system to generate positive ions and negative ions in surrounding air.

23. The method of claim 11, further comprising the step of:

exposing the space to a humidity of 70% to about 90%, wherein the step is conducted before the step of providing ozone.

24. The method of claim 11, wherein the enclosed space comprises a building.

25. The method of claim 24, wherein the enclosed space comprises a room of a building.

26. The method of claim 24, wherein the building comprises a dwelling.

27. The method of claim 11, wherein the enclosed space comprises a ship.

28. The method of claim 11, wherein the enclosed space comprises a passenger car.

29. The method of claim 11, wherein the enclosed space comprises a mobile home or a motor home.

30. A method for abating a pathogen, allergen, or odor in an enclosed space containing obstacles that greatly inhibit but do not entirely prevent the circulation of air, the method comprising the steps of:

providing an ingress into a first end of the space;

providing an egress out of a second end of the space, wherein the first end of the space and the second end of the space are situated on opposite sides of the space;

providing ozone to the space via the ingress;

maintaining the concentration of ozone in the air of the space as measured at the egress at a level of about 2 ppm to about 5 ppm for at least a time of from about 1 hour to about 3 hours;

controlling the relative humidity within the space at about 70% to about 90%; and

controlling the temperature within the space at about 15°C to about 27°C, wherein the steps of controlling the relative humidity and controlling the temperature are conducted substantially simultaneously as the step of maintaining the concentration of ozone, whereby the pathogen, allergen, or odor is abated.

31. The method of claim 30, further comprising the steps of:

ceasing providing ozone to the air of the space; and

permitting the concentration of ozone in the air of the space to return to an ambient level.

32. The method of claim 30, wherein the space comprises an interior of a wall in a building.

33. The method of claim 30, wherein the space comprises the interior of floor of a building.

34. The method of claim 30, wherein the space comprises an interior of a ceiling in a building.

FIGURE 1.

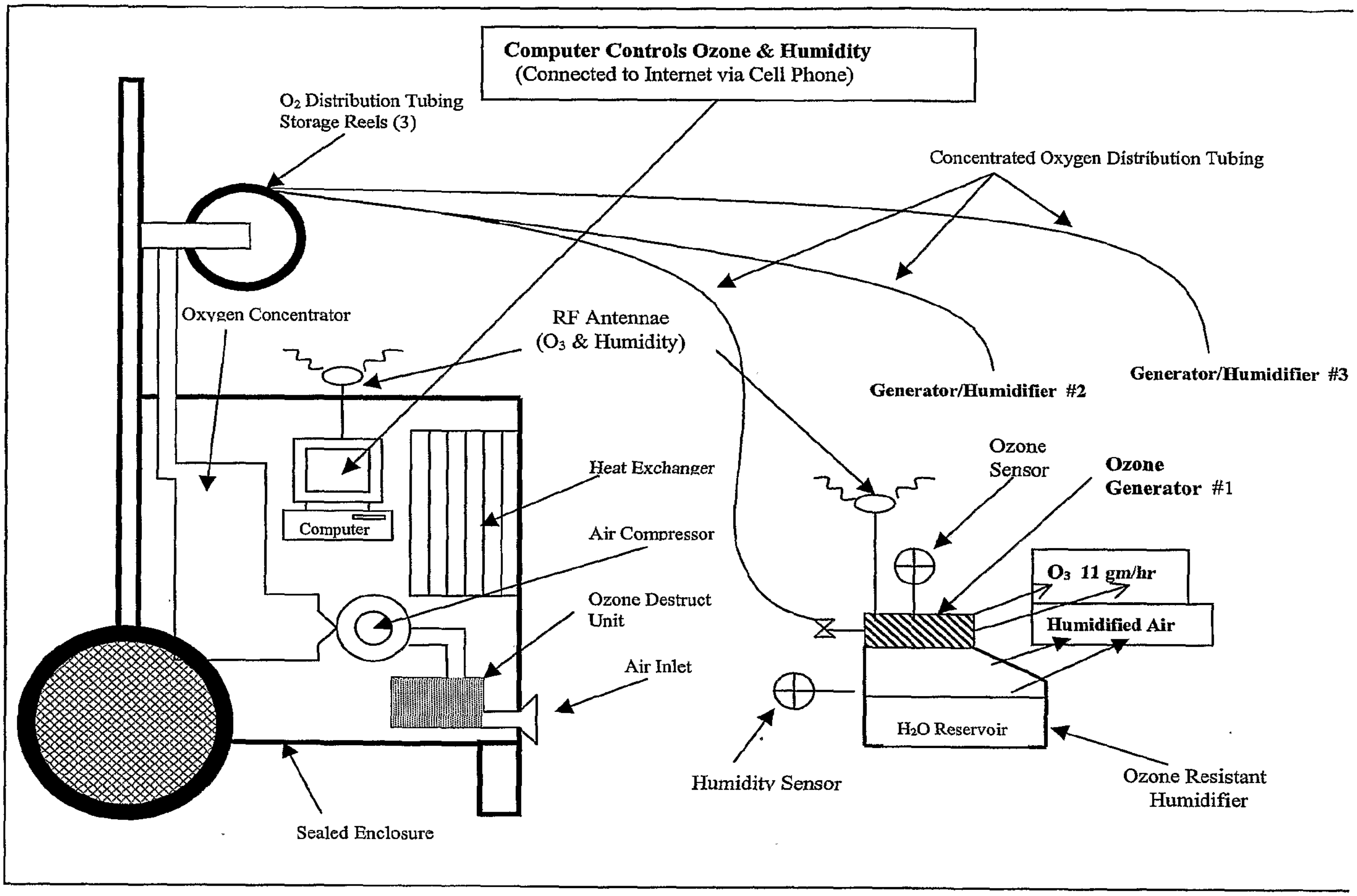

Computer Controls Ozone & Humidity
(Connected to Internet via Cell Phone)
O2 Distribution Tubing
Storage Reels (3)
Concentrated Oxygen Distribution Tubing
Oxygen Concentrator
RF Antennae
(O3 & Humidity)
Generator/Humidifier #2
Generator/Humidifier #3
Heat Exchanger
Computer
Air Compressor
Ozone Destruct
Unit
Air Inlet
Ozone
Sensor
Ozone
Generator #1
O3 11 gm/hr
Humidified Air
H2O Reservoir
Humidity Sensor
Ozone Resistant
Humidifier
Sealed Enclosure

FIGURE 2.

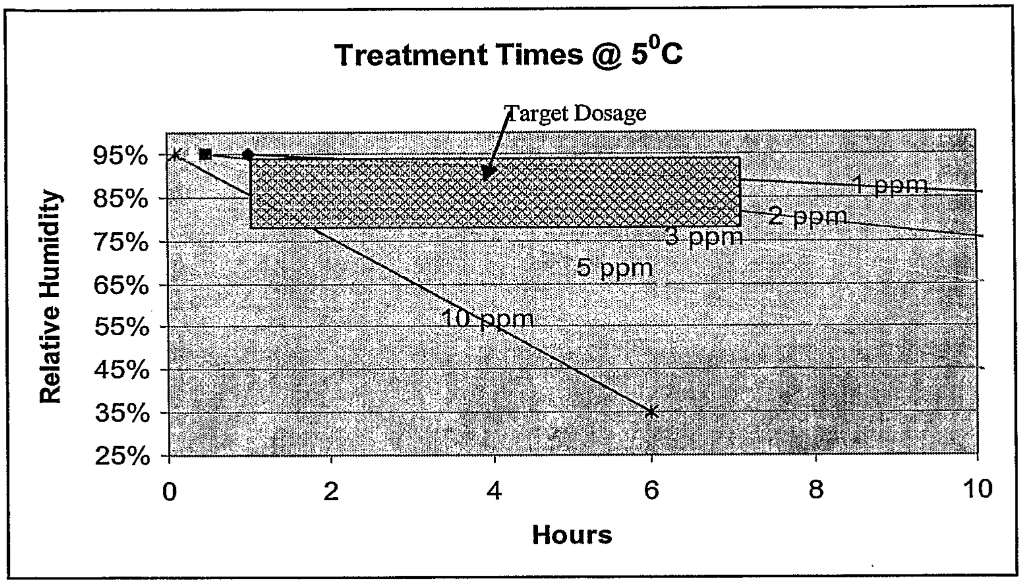

Treatment Times @ $5^0C$
Target Dosage
Relative Humidity
95%
85%
75%
65%
55%
45%
35%
25%
0
2
4
6
8
10
Hours
1 ppm
2 ppm
3 ppm
5 ppm
10 ppm

FIGURE 3.

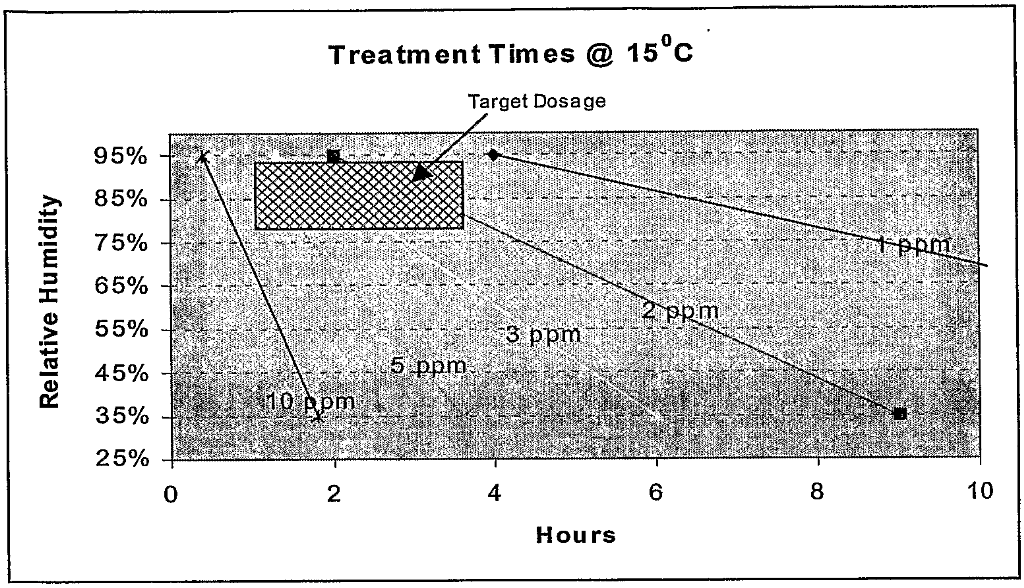

Treatment Times @ 15°C
Target Dosage
Relative Humidity
95%
85%
75%
65%
55%
45%
35%
25%
1 ppm
2 ppm
3 ppm
5 ppm
10 ppm
0
2
4
6
8
10
Hours

FIGURE 4.

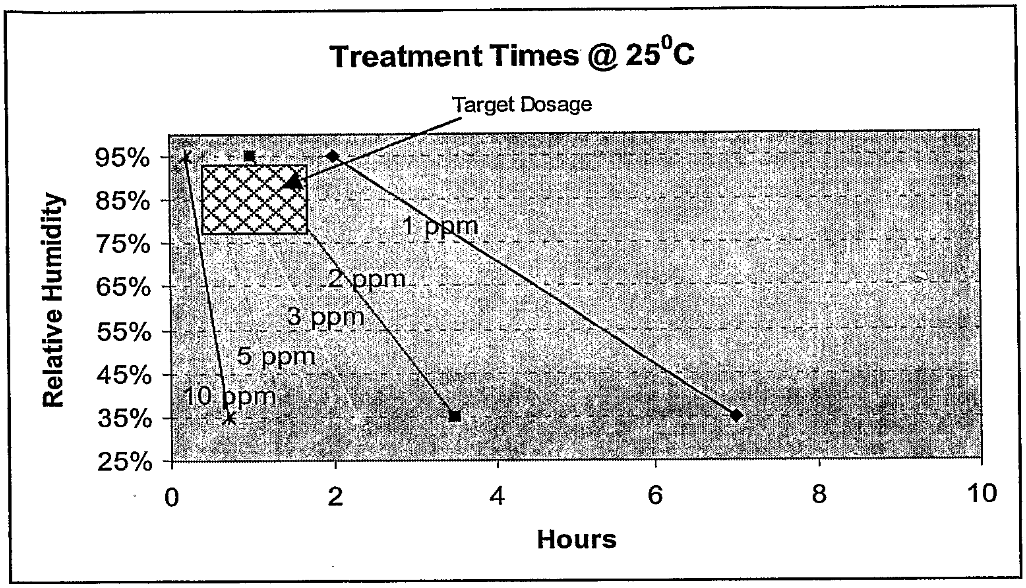

Treatment Times @ 25⁰C
Target Dosage
Relative Humidity
95%
85%
75%
65%
55%
45%
35%
25%
1 ppm
2 ppm
3 ppm
5 ppm
10 ppm
0
2
4
6
8
10
Hours

FIGURE 5.

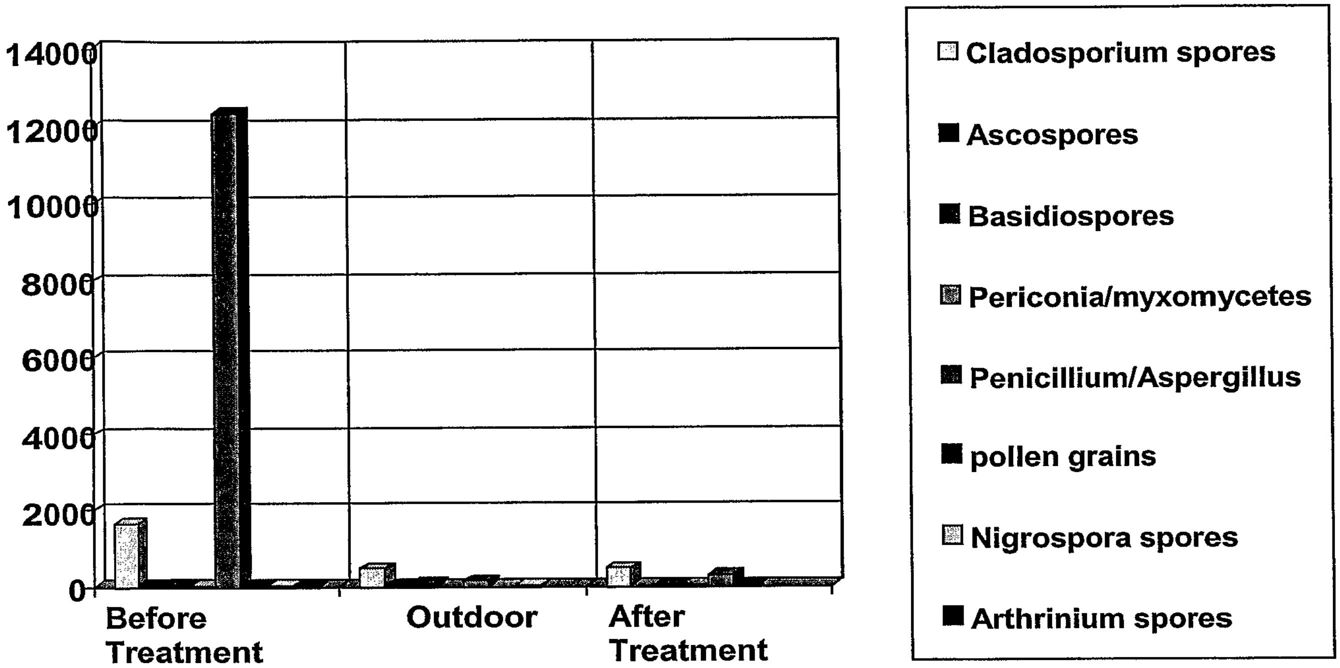

14000
12000
10000
8000
6000
4000
2000
0
Before Treatment
Outdoor
After Treatment
Cladosporium spores
Ascospores
Basidiospores
Periconia/myxomycetes
Penicillium/Aspergillus
pollen grains
Nigrospora spores
Arthrinium spores

FIGURE 6.

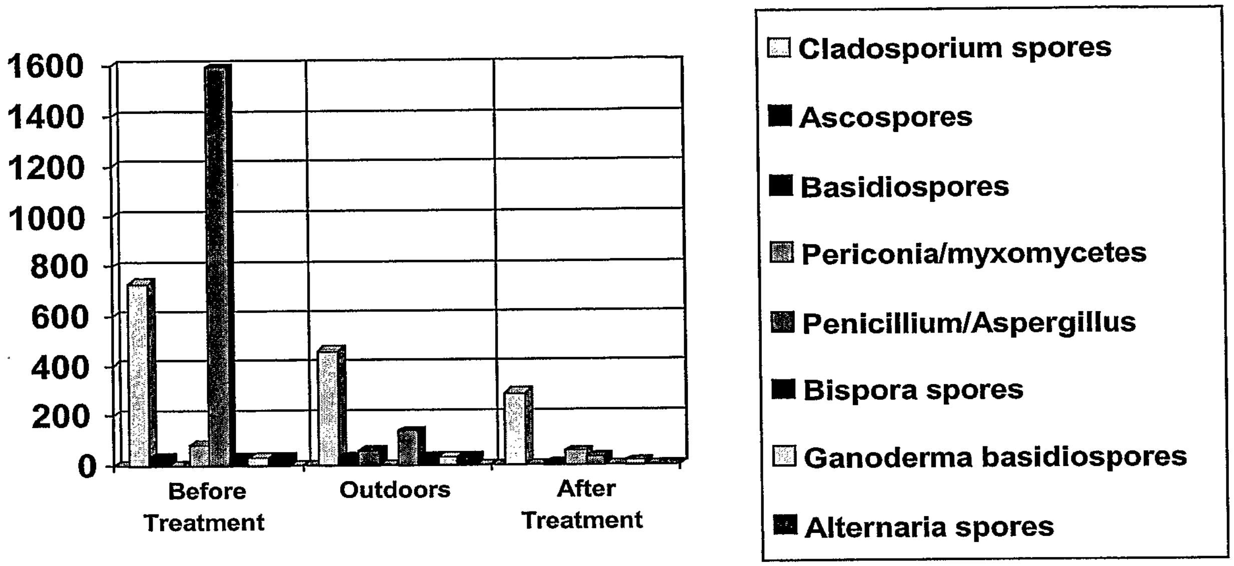
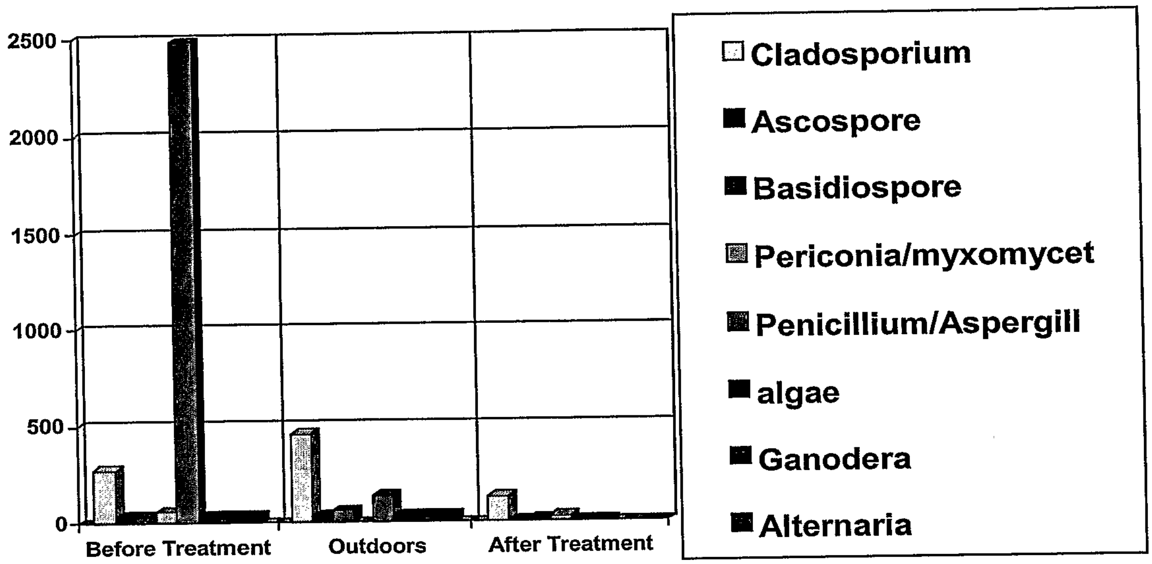

1600
1400
1200
1000
800
600
400
200
0
Before Treatment
Outdoors
After Treatment
Cladosporium spores
Ascospores
Basidiospores
Periconia/myxomycetes
Penicillium/Aspergillus
Bispora spores
Ganoderma basidiospores
Alternaria spores

FIGURE 7.


2500
2000
1500
1000
500
0
Before Treatment
Outdoors
After Treatment
Cladosporium
Ascospore
Basidiospore
Periconia/myxomycet
Penicillium/Aspergill
algae
Ganodera
Alternaria

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/US03/11800

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(7) : A61L 9/00, 2/00, 2/08, A62B 7/08, B01J 19/08
US CL : 422/1, 422/4, 422/5, 422/22, 422/24, 422/26, 422/28, 422/30, 422/34, 422/121, 422/124, 422/186
According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 422/1, 422/4, 422/5, 422/22, 422/24, 422/26, 422/28, 422/30, 422/34, 422/121, 422/124, 422/186

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EAST

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| Y,P | US 6,487,868 B2 (SATO et al) 03 December 2002, see entire document. | 1-11, 14, 23-30, and 32-34 |
| Y | US 6,313,470 B1 (FENCL et al.) 06 November 2001, see entire document. | 1, 11, 13, 15-22, and 30-31. |
| Y | US 5,752,878 A (BALKANY) 19 May 1998, see entire document. | 12 |

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 21 August 2003 (21.08.2003) | 11 SEP 2003 |
| Name and mailing address of the ISA/US<br>Mail Stop PCT, Attn: ISA/US<br>Commissioner for Patents<br>P.O. Box 1450<br>Alexandria, Virginia 22313-1450<br>Facsimile No. (703)305-3230 | Authorized officer<br>MONZER R. CHORBAJI<br>Telephone No. (703) 308-0661 |